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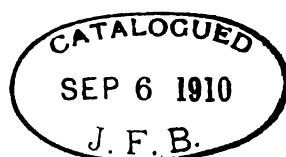
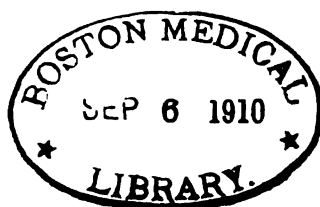
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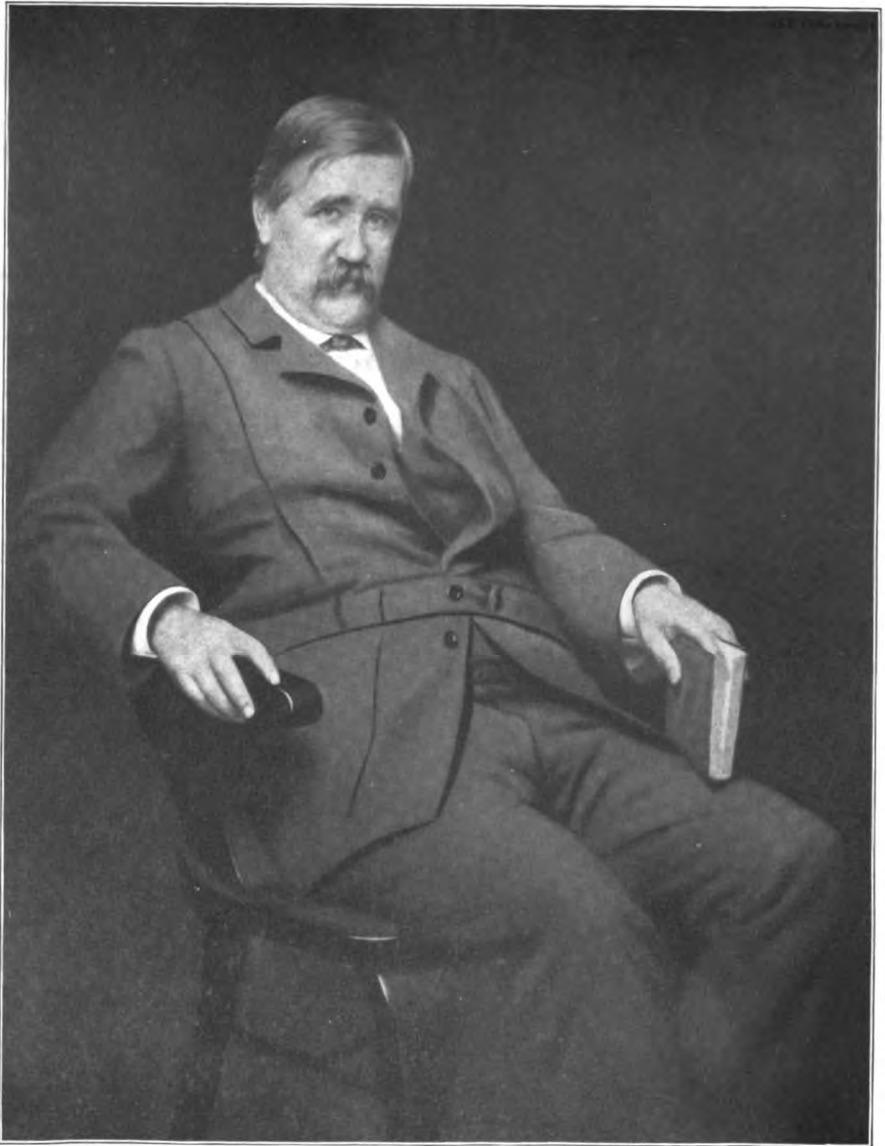
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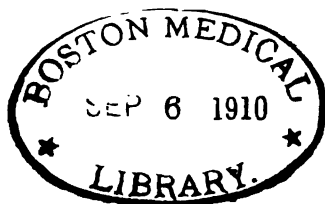
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WILLIAM KEITH BROOKS



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ANATOMICAL RECORD

Vol. III.

JANUARY, 1909.

No. 1

THE LIFE AND WORK OF PROFESSOR BROOKS.

BY

EDWIN G. CONKLIN.

In the death, on November 12, 1908, of William Keith Brooks, Professor of Zoölogy in the Johns Hopkins University, American science has lost one of its most distinguished representatives and his friends and associates a noble and lovable companion. Through his work as an investigator and teacher he has left a deep impression on the sciences of anatomy and zoölogy, and a brief account of his life and work cannot fail to be of interest to all morphologists.

He was born at Cleveland, O., March 25, 1848, the second son of Oliver Allen and Ellenora (Kingsley) Brooks. Both of his parents were natives of Vermont; his great-grandfather served in the battle of Concord, and for five generations before the Revolution his paternal ancestors lived in or near Concord, the first of the name having come from England to America prior to 1634.

Young Brooks received his early education in the public schools of Cleveland. One of his teachers, who is still living, remembers that he was a serious student, deeply interested in natural history. A fresh water aquarium furnished him much interest and instruction, and he devoted much attention to the habits of birds.

After leaving the Cleveland high school, he entered Hobart College, Geneva, N. Y., where, he says, "I learned to study, and, I hope, to profit by, but not to blindly follow, the writings of that great thinker on the principles of science, George Berkeley." He spent two years

at Hobart, where he took high honors, and then entered the junior class at Williams College. Here he distinguished himself as a thorough and independent scholar, and is said to have been one of the most brilliant students in mathematics Williams had ever known. In 1870 he received the degree of bachelor of arts and was elected to Phi Beta Kappa.

One of the classmates at Williams says, "He cared nothing for marks and prizes in college, was very liable to burn the midnight oil over some subject that specially appealed to him and then cut prayers and early recitations the next morning. He never put himself forward to answer the questions of the class room, but when called upon always gave a good account of himself." Another friend who knew him in college, now a distinguished professor of zoölogy in one of our great universities, says that he took an active part in the Lyceum of Natural History at Williams, and that his room was a favorite meeting place, evenings. Brooks had a microscope and with it he showed many interesting things to his fellow students. On one occasion he undertook to demonstrate a cross section of a hair and after much difficulty in cutting a free-hand section he lathered and shaved a portion of his face and then engaged the students in other things while he waited a half hour for the hair to grow before he shaved again.

After his graduation his father took him into mercantile business with himself, but such work was distasteful to young Brooks and he soon abandoned it and in 1871 became a teacher in De Veaux College, Niagara Falls, N. Y., where he remained for two years. In spite of his love for natural history he was undecided when he left college whether to devote himself to mathematics, to Greek, or to biology, for he was unusually proficient in all of these subjects. He finally decided to specialize in bio'ogy, largely influenced, we may imagine, by the philosophical importance of the doctrine of evolution.

At Harvard Louis Agassiz was at the climax of his wonderful career and thither flocked many young men, who afterward became leaders in biological science, to study under this great master; among these was Brooks. In the summer of 1873 he was a student at Agassiz's laboratory on the island of Penikese in Buzzards Bay, and

from that time until his death he remained a student of marine life. The sea with its teeming multitudes of living things always had a particular charm for him, not merely because of the interest and variety of its forms of life, but also because it was the scene of the earliest acts in the drama of evolution. From this time forward throughout almost his whole life he spent a part at least of every summer at the shore; in 1874 he was again at Penikese at the last session of that famous laboratory; in 1875 he was with Alexander Agassiz at his private laboratory in Newport, R. I., working on the Embryology of Salpa; in 1876 and again in 1877 he was with the U. S. Fish Commission; in 1878 began the sessions of the Chesapeake Zoölogical Laboratory, which he founded and which he directed for many years. His scientific life was thus closely identified with marine laboratories, beginning with the earliest of these at Penikese and ending with the latest at Tortugas, Fla.

In 1875 he received the degree of Ph.D. from Harvard University. During his life in Cambridge he had the stimulus of intimate friendship with Hyatt and McCrady, each of whom by his influence and example helped to shape the career of Brooks. In the summer of that year he with others organized a laboratory for instruction in biology in Cleveland. In his address at the dedication of the biological laboratory at Western Reserve University, in 1899, he described that enterprise in the following words:—"It was my good fortune to have a share in one of the first attempts to organize laboratory instruction in Cleveland, and I hope you will pardon me if, on this occasion, my mind runs back to this old undertaking. In 1875 three young men who had begun to train themselves as naturalists, came together for their summer vacation, at their homes in Cleveland. They were Theodore B. Comstock, afterwards President of the University of Arizona; Albert H. Tuttle, now Professor of Biology in the University of Virginia, and myself. We were filled with enthusiasm for our work, and, like all earnest students from Chaucer's day to this, as glad to teach as to learn, and we determined to organize a summer class for laboratory instruction in zoölogy and botany. Money for our expenses was liberally supplied by R. K. Winslow, Leonard Case, and other citizens; the authorities

granted us the use of the old high-school building on Euclid avenue near Erie street, and we were soon able to issue notices of our undertaking, and invitations to all who wished to join the class, asking them to do so without the payment of any fee. Some twenty-five were soon enrolled, most of them teachers, some from a distance, and work was begun with a class which shared all the earnestness and enthusiasm of their instructors. We had daily lectures or demonstrations, followed by four or five hours of work in the laboratory, while two afternoons in each week were given to excursions to Rocky River, Cuyahoga Falls, and other places favorable for the out-of-door study of nature. As a small steamboat had been placed at our service, we made two excursions upon the lake, and thus gave to the class an opportunity to learn the use of the naturalist's dredge for collecting the animals of the bottom. Our work was in part the study of the animals and plants which we obtained on these expeditions, and we also made use of a supply of marine animals which had been gathered for the purpose at the seashore." This account is interesting not merely as a bit of local history, but rather because it reveals thus early in his career his love of teaching and his methods of instruction; the latter, we may be sure, largely influenced by his experience at Penikese.

During the year 1875-76 Brooks was assistant in the museum of the Boston Society of Natural History, and on the founding of the Johns Hopkins University in 1876 he applied for and obtained one of their twenty famous fellowships, which have done so much to change the character of university work and ideals in this country. Before he entered upon his fellowship his abilities as a teacher were recognized and he was appointed associate in biology. In 1883 he was appointed associate professor of morphology and in 1889 professor in that subject. On the retirement of Professor H. Newell Martin from the headship of the Biological Department in 1894, Professor Brooks became head of the department and continued in that position until his death. His active scientific life was therefore coextensive with that of the Johns Hopkins University, and his love of the Biological Department and his loyalty to his University were among his strong characteristics.

Although his publications were numerous and important I think that his influence was greatest and most far reaching in his work as a teacher and scientific director. To few biologists, perhaps to no other in the history of this country, has it been given to direct the work and shape the scientific ideals of so large and influential a body of young men. Among those who took their doctor's degrees under him are more than a score of the leading zoölogists of this country, while many other distinguished scholars of this and foreign lands were his pupils.

As a teacher, Professor Brooks was characterized by his breadth of view and his interesting and illuminating style, rather than by his accuracy in details. Like all great teachers he knew that the primary purpose of teaching is inspiration and illumination, and that information is only of secondary importance. A candidate for the doctor's degree expressed to Professor Brooks, on the morning after his major examination, his mortification that he had blundered in answering one of the questions. With apparent seriousness Brooks said: "Your mistake is a serious one, for it makes you responsible for misinforming my whole class on that subject; I used your answer as my lecture this morning."

He was an artist of much ability and his drawings were made with much care; in general they were not only accurate but also artistic. He expected all his students to learn to draw, and he frequently said to them, "You can't do anything well without patience." He loved to work with simple apparatus and his technique was never complicated. He never mistook paraphernalia for science, and he went directly to the end he sought.

Although Professor Brooks would present a subject in his lectures in the clearest and most entertaining manner, he rarely, if ever, attempted to smooth the path of the investigator; the latter was to a very large extent thrown upon his own resources. He believed so thoroughly in the law of natural selection, as he once said, that he thought it was best for a student to find out for himself, as soon as possible, whether he was fitted for independent investigation or not, and by this rigid discipline the unfit were weeded out from the fit. This was certainly no school for weaklings, but it afforded

magnificent training for those who had ability and determination. For those who endured this ordeal he maintained the warmest regard, and his interest and pride in the work of his students was as marked as it was stimulating.

In connection with his work as teacher and director must be mentioned the establishment by him of the Chesapeake Zoölogical Laboratory in 1878. This was the second marine laboratory in this country founded for advanced work in pure zoölogy, the first being the Penikese Laboratory, established by Louis Agassiz in 1873. The Chesapeake Laboratory, unlike the one at Penikese, was not limited to one place; it consisted neither of buildings nor fine equipment, but of men and ideas. For the first few years of its existence it was situated at several different points on Chesapeake Bay; afterwards it was located at Beaufort, N. C., then at different places in the Bahama Islands, and finally in Jamaica. In the various expeditions of Brooks and his students to these different places they made not only a thorough biological survey of each region, but they did work of most fundamental and far-reaching importance on the various groups of animals found. Out of these expeditions has grown the beautiful and permanent station of the U. S. Fisheries Bureau at Beaufort, N. C., in which Brooks took great interest and pride. It was on these expeditions that his students came to know him most intimately and affectionately. In the memory of each of them is fixed some scene of his enthusiasm over the discovery of a rare specimen or an unknown stage in some life history; his long vigils full of exciting discoveries; his quiet talks on nature and philosophy, after the day's work was done.

The "Scientific Results of the Sessions of the Chesapeake Zoölogical Laboratory" were at first published as a separate journal of which Brooks was the founder and editor, later this was incorporated in the "Studies from the Biological Laboratory" of which he was joint editor with H. Newell Martin. He subsequently established and edited "Memoirs from the Biological Laboratory," a large quarto for the publication of important monographs. He was also one of the editors of the *Journal of Experimental Zoölogy*.

As a scientific investigator Brooks showed sound judgment, depth of insight, and untiring industry and enthusiasm. In his

researches he did not attempt to cover the whole field of zoölogy, but he did attempt to do thoroughly and well all that he undertook. His work began at a time when descriptive embryology was the newest and most promising branch of zoölogy and much of his earlier work was devoted to this field. His first important paper was on the "Development of Salpa," and many of his later works, some of them monumental monographs, were devoted to the anatomy, embryology and evolution of this interesting group of ascidians. Indeed his latest work, which was left in manuscript and for which he had prepared hundreds of beautiful drawings, was a continuation of his great "Monograph on the Genus Salpa." Among other important researches may be mentioned his studies on the "Lucayan Indians," on the "Development of Marine Prosobranchiate Gasteropods," "Early Stages in the Development of Fresh Water Pulmonates," "The Development of Lingula and the Systematic Position of the Brachiopoda," "The Relationship of Mollusca and Molluscoidea," "The Life History of the Hydromedusæ," "The Stomatopoda of the Challenger Expedition," "Lucifer: A Study in Morphology," "The Embryology and Metamorphosis of the Macroura" (with F. H. Herrick), and a "Monograph of the Genus Doliolum."

His studies on the development of mollusks led him to an examination of the life history and habits of the oyster. He discovered that the eggs of the oyster could be fertilized artificially and this was followed by a consideration of the best methods of propagating and cultivating oysters. His work on this subject was embodied in a book called "The Oyster," which has recently appeared in a second edition. Because of its economic importance, Brooks has been more widely known through this work than through any other. He was made chairman of the Maryland Oyster Commission and did much to improve this industry by a scientific treatment of the subject.

He wrote but one text-book, his "Handbook of Invertebrate Zoölogy" (1882), but this was so excellent that it still remains a model, and in some respects has not been excelled, if equalled, by any later book on that subject. He was also the author of many scientific articles of a popular sort, in which work he showed unusual

ability. He was inclined to look upon various human problems, such as the education and political position of woman, from the standpoint of zoölogy, and his popular discussions of the possible improvement of the human race, of instinct and intelligence, of heredity and variation, etc., were both novel and suggestive.

His chief interest was always in the philosophical side of biology and into this he put the larger part of his life work. Even the special researches, some of which have been named above, were permeated by philosophical inquiry, and most of his books and later contributions were devoted to the deeper philosophical meanings of vital phenomena.

As a boy he had read the works of Darwin and had been immensely impressed by them and to the last he yielded to no one in his admiration and reverence for that great master. Probably no other disciple of Darwin was more thoroughly acquainted with his works, and very frequently when criticisms of Darwinism appeared he would point out the fact that the critic did not understand what Darwinism is, or that Darwin had already met and answered the objection raised.

In 1884 he published a book entitled "The Law of Heredity," which in some respects anticipated the theories of Weismann, and De Vries, and which won the highest commendation from Huxley and other leaders of biology. But probably the book by which he will be longest remembered is the series of lectures delivered at Columbia University and published in the Biological Series of that institution under the title "The Foundations of Zoölogy (1899). In this book he deals with many subjects fundamental not only to zoölogy, but to science and philosophy in general. Among these may be mentioned "Nature and Nurture," "Zoölogy and the Philosophy of Evolution," "Natural Selection and the Antiquity of Life," "Natural Selection and Natural Theology," "Paley and the Argument from Contrivance," "The Mechanism of Nature," "Louis Agassiz and George Berkeley," etc. On the whole his chief points of view may be summarized in his oft-quoted remark of Aristotle that the "essence of a living thing is not what it is made of nor what it does, but why it does it," or as he expresses it elsewhere, "the

essence of a living thing is not protoplasm but purpose;" and in the further statements, which he draws from Berkeley, that "nature is a language," that "phenomena are appearances," and that "natural laws are not arbitrary nor necessary, but natural, *i. e.*, neither less nor more than one who has the data has every reason to expect." In his philosophical writings he was most deeply influenced by Aristotle, Berkeley, Darwin, and Huxley.

On his fiftieth birthday, March 25, 1898, his former students united in presenting to him an oil portrait of himself (see frontispiece) together with a congratulatory address, and at the end of his book on the "Foundations of Zoölogy," he added on this date, the following note:

"For you who have, at this time, for my encouragement, called yourselves my students, I have written this book which has been my own so long that I should part with it with regret, did I not hope that, as you study the great works to which I have directed you, you may still call me teacher. If you are indeed my students, you are not afraid of hard work, so in this day of light literature, when even learning must be made easy, you must be my readers, and you must do double duty; for I take the liberty of a teacher with his pupils, and ask that, after you have read the book, you will some day read it again; since I hope that what may seem obscure, may, on review, be found consistent and intelligible."

Much that he has written still seems to me obscure, although I have read it more than once, but I bear in mind his parting request, and in the meantime profit by that which I do understand and am charmed by the classical and almost poetical diction in which it is written. Whatever one may be inclined to say of his conclusions and theories, it cannot be denied that in an age when biological investigators have been content with discovering phenomena, he attempted to go back of phenomena to their real meaning and significance and to point out the relationship of these newly discovered phenomena to the great current of philosophy which has flowed down to us from the remote past.

In his review of this book under the caption "A Sage in Science," David Starr Jordan said:—"Brooks' lectures on the Foundations of

Biology constitute a book that will live as a permanent addition to the common sense of science. It belongs to literature as well as to science. It belongs to philosophy as much as to either, for it is full of that fundamental wisdom about realities which alone is worthy of the name of philosophy. Writers of literature have been divided into those with quotable sentences, such as Emerson and Thoreau, and those whose style runs along without break in the elucidation of matter in hand, as Hawthorne and Irving. To the former class Brooks certainly belongs. His lectures are full of nuggets of wisdom, products of deep thought as well as of careful observation. There is not an idea fundamental to biology that is not touched and made luminous by some of these sagacious paragraphs. Whether it be to show the significance of some unappreciated fact, or to illustrate the true meaning of some complex argument, or to brush away the fine-spun rubbish of theory, the hand of the master is seen in every line." . . . "The stones which Dr. Brooks has chosen as 'Foundations of Zoölogy' will remain for centuries, most of them as long as human wisdom shall endure. The volume is a permanent contribution to human knowledge, the worthy crown of a life of wise thought as well as of hard work and patient investigation. The biologists of America have long since recognized Dr. Brooks as a master, and this volume, the modern and scientific sequel to Agassiz's 'Essay on Classification,' places him in the line of succession from the great interpreter of nature, whose pupil and friend he was." (Science, No. 224).

His abilities received early and generous recognition. Apart from his university advancement, he received many honors. He received the honorary degree of LL.D. from Williams College in 1893, from Hobart College in 1899, and from the University of Pennsylvania at the Franklin Bicentenary, in 1906. In 1884, at the age of thirty-six, he was elected a member of the National Academy of Sciences; he was chosen a member of the American Philosophical Society in 1886; of the Academy of Natural Sciences of Philadelphia in 1887; he was also a member of the Boston Society of Natural History, the American Academy of Arts and Sciences, of the Maryland Academy of Arts and Sciences, and of the Ameri-

can Society of Zoölogists; he was a fellow of the American Association for the Advancement of Science, and also a fellow of the Royal Microscopical Society. For his work on the oyster he received the medal of the Société d'Acclimatation of Paris; for his work on the scientific results of the Challenger Expedition he was given a Challenger Medal; and he received a medal at the St. Louis Exposition of 1904, where he gave an address. He was Lowell Lecturer in Boston in 1901, and he gave one of the principal addresses before the International Zoölogical Congress at Boston in 1907.

In his home life Professor Brooks was most happy and devoted. He married in June, 1878, Amelia Schultz of Baltimore, a woman of simple and charming personality. Two children were born to them, Charles E. Brooks, who took the degree of Ph.D. in mathematics at the Johns Hopkins University, and who now resides at Elizabeth, N. J., and Menetta W. Brooks, a graduate of Vassar College, who, after the death of Mrs. Brooks in 1901, took charge of her father's home and became his daily companion. One of the most delightful memories which zoölogical students have of their life in Baltimore is of those pleasant evenings spent at his home when biological classics were read and discussed, when the various biological expeditions were talked of, and, in lighter vein, when the sayings of the children were reported, the animal pets shown, and the home-grown orchids exhibited. No one who experienced it can ever forget the simple and cordial hospitality of Professor and Mrs. Brooks, nor the sense of deep and abiding happiness which these glimpses of their home life gave.

Professor Brooks once told the writer of this sketch that he proposed to retire from his university position when he had reached the age of sixty, and thereafter devote himself entirely to philosophical and scientific work. He reached the age of sixty last March, but how different was his realization from his plan. His retirement was not to the scholarly leisure for which he longed but to pain, weakness and mortal sickness. For nine months he struggled against a complication of organic heart trouble and kidney disease, and at sunrise on Thursday, November 12, he breathed his last.

Personally Professor Brooks was rather short and stout, slow and deliberate in his movements and speech, and undemonstrative in

manner. Mere conventionalities counted for little with him; he was simple, sincere, and natural. With him talking meant expressing ideas, not merely passing the time, and if he had no answer ready when a question was asked him, he usually gave no answer until he was ready—it might be several days later,—when he would answer as naturally as if the question had been asked only a moment before. He was often so absorbed in his work that he paid little attention to his dress, and he would sometimes humorously say that he envied the man who was not compelled to wear a collar or necktie, or to have his hair cut. These characteristics made him appear somewhat unique and picturesque, and gave rise to many charming anecdotes about him, which his students and friends relate with merriment, but real affection.

He was a man of wide culture, though his absorption in his work was so great that many knew him only as a naturalist. He knew well the world's best literature and art, and in his later years he found that he had a strong liking for music, especially the great compositions of Beethoven, Mozart, Wagner and Bach.

One of his strongest characteristics was his judicial and philosophical temper. When he was once asked if he did not fear that some one would anticipate him in his great work on *Salpa*, on which he had worked for many years, he said, "I long since ceased to be troubled by such thoughts, for if another shou'd publish on this or any other subject before I do, his work would probably be better or worse than mine. If it was better I should be glad to be saved the mortification of having published poorer work; if worse, it would only afford additional material for my paper." His mind was too large for little things, too sane for foolish ones. He was remarkably original and suggestive in his methods of thought, and in his views of scientific, social and philosophical problems he was as artless and direct as a child. He was critical, yet tolerant; modest, but dignified; loyal to his friends, his University, and his ideals; independent in thought and action, and not easily moved from a position he had once taken.

He was kind and gentle; and neither in his publications nor in his relations with students did he ever deal in scorn, irony, nor

invective. President Remsen said that he had been called the most lovable man in the faculty. His interest in his former students was genuine and hearty, though he rarely expressed it directly to the person concerned. "One of the joys of a teacher," he once said, "is to see his students surpass him." On the other hand his students delighted to honor him; and on the occasion of his promotion to a full professorship, on his fiftieth birthday, at the twenty-fifth anniversary of the founding of the Johns Hopkins University, and at the International Zoölogical Congress in Boston, they showed him how deep a place he held in their affections. On December 31, 1908, sixty of his former students met in Baltimore to pay honor to his memory, and the occasion was one of delightful reminiscence and of grateful recognition of indebtedness to him.

What was the secret of his remarkable influence over others, which his students and associates recognize? By general consent it is attributed not merely to his greatness as an investigator and teacher, but also to his character as a man. In his life there was nothing either to be concealed or explained. He was "a man in whom there was no guile;" a man of such transparent simplicity and sincerity, of such single-hearted devotion to science, so simple-minded, natural, pure in thought and deed, that his *life* as well as his *work* has left an indelible impression upon all who knew him.

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CONSERVATISM IN ANATOMY.¹

BY

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When our colleagues of other societies are commemorating the centenary of the birth of Charles Darwin and, at the same time, the semicentenary of the publication of the great work which placed upon a firm basis the most fertile philosophical theory the world has ever known, it seems fitting that we too, as Anatomists, should make acknowledgments of our indebtedness to him for having laid the foundation upon which Anatomy has grown to be a science in fact as well as in name, for having furnished the thread of theory, which, as a golden weft, weaves the warp of facts into a substantial fabric. And in some ways we are especially interested, for the bitter opposition Darwin's views at first encountered in certain quarters was largely based upon the question of their applicability to the origin of Man, and Darwin himself tells us that "The Descent of Man," published in 1871, was written for the purpose of determining "how far the general conclusions arrived at in my former works were applicable to man." And he further states "This seemed all the more desirable as I had never deliberately applied these views to a species taken singly."

Until Darwin's time Anatomy was essentially a descriptive science, if such an expression may be used, if anything which is merely descriptive can properly be termed a science. The objective for which Anatomists strove was the most thorough description possible of the structure of the body, a perfect and detailed exposition of the facts of human anatomy. A basis for a determination of the significance of the facts, except a teleological one founded upon physiological or,

¹Presidential Address, Association of American Anatomists, December 29, 1908.

in some cases, theological, considerations, was lacking, and, to use a trite simile, Anatomy was like a structure built of stones most carefully piled, but lacking the mortar necessary to bind them together into a substantial edifice. This mortar Darwin supplied, and even although some parts of our building are still but imperfectly supplied with it, yet we have the satisfaction of showing our visitors through many parts which are well built, solid and substantial.

But it must be admitted that Darwin's contributions to Anatomy were indirect rather than direct, for, greatly to his regret in later years, his anatomical studies during his student days were conducted under depressing and, to him, most distasteful conditions. In his brief autobiography he gives a moving picture of the course at Edinburgh, speaking thus, "The instruction at Edinburgh was altogether by lectures, and these were intolerably dull, with the exception of those on chemistry by Hope; but to my mind there are no advantages and many disadvantages in lectures compared with reading. Dr. Duncan's lectures on *Materia Medica* at 8 o'clock on a winter's morning are something fearful to remember. Dr. — — — made his lectures on human anatomy as dull as he was himself, and the subject disgusted me. It has proved one of the greatest evils in my life that I was not urged to practise dissection, for I should soon have got over my disgust; and the practice would have been invaluable for all my future work. This has been an irremediable evil, as well as my incapacity to draw."

The teacher whose methods were so deterrent was Alexander Munro, the third of the famous trio of that name who presided over the destinies of Anatomy at Edinburgh for a period of 139 years. He was, however, an unworthy successor to his more illustrious father and grandfather, and was not a teacher likely to arouse enthusiasm in Darwin. For his style has been described by a biographer as "confused, prolix and illogical," all characteristics which must have been highly distasteful to one whose mind worked clearly, concisely and logically. We must regret that Darwin did not accompany his brother Erasmus to "Mr. Sizars on Anatomy, who is a charming lecturer," for had his interest in the subject been aroused what possibilities there are that his keen powers of observation and

marvellous faculty for perceiving correlations and significances might have supplied material for the expansion and elaboration of the first chapter of the "Descent of Man," thereby making it, to even a greater extent than it is in its present form, a notable monument to his scientific insight.

Perhaps in no department of science was the stimulus which Darwin supplied more needed than in Anatomy. For, owing to the relation which that science held to the practice of medicine and surgery, there was an imminent danger that it would be cultivated solely on account of its applications, and its teaching thereby become formal. It needed a lamp to guide it past the pitfalls of empiricism and teleology into which it had often stumbled, and show it the way along the broad path leading to a solid foothold on the rock of Science. And that was the lamp which Darwin supplied. But Anatomists have ever been most conservative men, and it was long before many of the rank and file were content to regard the guiding light as other than a will-o' the-wisp, while others lingered so far behind the torch-bearers that they could only grope in their shadows for the path they knew existed. The torch-bearers are more numerous to-day and the light is brighter, but, with our old conservatism, we still garb ourselves for our journey in some of the garments of the past, even though they may be travel-worn and ill-fitting. I must confess for myself a lingering affection for such antique vestments, and am ready to cry with Teufelsdröckh, "Friends, trust not the heart of that man for whom old clothes are not venerable." But veneration does not demand utilization, and may be quite as sincere when its objects are safely stored in an historical museum, as when they are borne upon our shoulders on the journey, often to our inconvenience and discomfort.

It has been said that man is a slave to conventionality, but I do not know that the statement is truer of man than it is of his fellow animals. But granting that it is true, we Anatomists but show our kinship to the rest of the human race by bearing our badges of servitude with a faithfulness that under other circumstances might be commendable. For conventionalism is deeply rooted in our methods, so deeply, indeed, that we often fail to perceive its true sig-

nificance and cheerfully struggle along beneath the burden it imposes upon us. It may be worth while, therefore, to devote the time which conventionality demands shall be occupied by the President of this Association in an inaugural address, to pointing out some of the other conventionalities which we continue to inflict upon ourselves and upon our students. Perhaps that last statement is too personal, for many of our members have shown a laudable desire to rise above conventionalities. Let me rather say, therefore, impersonally, that I wish to direct your attention to some conventionalities in the methods of teaching Anatomy.

Conventionalities are the survivals of adaptations, useful in the past but now merely rudimentary organs, like the buttons on our coat sleeves. Let us recall the conditions which obtained at the time of the revival of Anatomy in the sixteenth century, and note the adaptations to these conditions in the methods employed in teaching it. The immediate result of the publication of Vesal's great work was, naturally, a great awakening of interest in practical anatomy. It is well known, of course, that dissection was practised before 1543, and it was even employed for the purpose of instruction. Sylvius gave demonstrations with his lectures, and Vesal and his fellow students had access to the cadaver in the intervals between the demonstrations. Berengarius, who taught anatomy at Bologna for twenty-five years, until 1527, expressly recommended his students to make dissections, and even long before that date Guy de Chauliac (1363) tells us that his teacher, Bertucci, had made several dissections, dividing each into four lessons, whence it may be conjectured that they were demonstrations. But the attention given to practical anatomy in the præ-Vesalian days was slight compared with that aroused by the clear demonstration of its importance that Vesal gave. Anatomical demonstrations, or Anatomies, as they were called, became the fashion and professorships of Anatomy, distinct from the chair of Medicine, began to be established that these Anatomies might be regularly conducted. Special buildings in which the demonstrations could be given were soon in demand, and since subjects were scarce and those desiring to attend the Anatomies many, the style of building naturally adopted was that of the amphitheater. Before the end of

the fifteenth century Benedetti had secured the erection at Padua of a spacious amphitheater on the plan of those at Rome and Verona, but this was apparently merely a temporary structure, for Fabricius, while Professor of Anatomy at Padua, obtained in 1594 a decree from the Venetian Senate ordering the erection of another building of the same style for his accommodation. Somewhere about the middle of the sixteenth century an anatomical amphitheater was erected at Pisa, in 1552 another was built at Pavia and four years later Rondelet secured a similar building for the University of Montpellier.

And so the leaders of the revival of Anatomy adapted their methods and facilities to the new conditions, and excellent the adaptations were. In his amphitheater the Professor of Anatomy described as fully as his knowledge permitted the structures which he himself laid bare as he talked, or which were exposed for him by a dissector, the prototype of our present-day prosector, while clustered about the table or seated upon the benches of the theater were the students and physicians, who came to learn from the lecture and see what they could of the demonstration, and the notabilities, who had the entrée to the Anatomies and to whom they were more or less a fashionable spectacle. With the exception of these latter auditors, how similar was the method of instruction in those early days to that we may even now see in some of our medical schools, and that although the conditions in which we find ourselves are altogether different. We have anatomical laboratories to take the place of anatomical theaters, the student instead of merely watching a demonstration may himself perform a complete dissection, his work extending over weeks instead of being limited to a few days, and wise legislation has been enacted for the provision of an adequate supply of material for laboratory instruction. And yet with all these opportunities for obtaining direct and personal knowledge of anatomy there are those who still cling to the sixteenth century garments. The students at one hour of the day assemble in an amphitheater to witness an Anatomy and at another hour they meet in the laboratory to perform anatomies for themselves. Does it not border on the absurd, this juxtaposition of sixteenth and twentieth century methods! If any advantage accrued from the reten-

tion of the old method its conservation would be most laudable; but this cannot be urged in its favor. The amphitheater is far from satisfactory either for the lecturer or for the auditors and, in addition, is most wasteful of space. How many of a class of one hundred or even of fifty can see with any useful distinctness what the teacher is demonstrating in the depths of such an auditorium. I do not, however, wish to condemn outright the demonstration method of instruction. It has undoubtedly great possibilities and may be made a most useful adjunct to the work of the laboratory if the demonstrations are given to small sections of the class and especially if the students be made to take part in it. But it is the wholesale demonstration, conducted along the antique lines, that I condemn as a waste of valuable time both for the student and the instructor.

In the early days of the revival of Anatomy books were few and those that were available were expensive, so that the lectures accompanying the demonstrations were important parts of the method of instruction. Indeed, what knowledge of descriptive anatomy the student obtained was largely from the lectures. New discoveries and new ideas were slow in disseminating and slower still in becoming incorporated in text-books, so much so that we find Dionis as late as 1694 giving as a reason for the publication of his lectures the lack of any text-book to which he could refer his students for information concerning the circulation of the blood, the books most largely used at that time, those of Riolan and Bartholin, possessing "a somewhat ancient ferment of antique opinions, which flavors all their works." It is interesting also to notice that Dionis added illustrations to his book that it might play the part of the demonstrations as well as that of the lectures, the former being so rare in France, outside Paris, that the physicians of the provinces scarcely had an opportunity for seeing one throughout their whole lives. The lecture, then, in the sixteenth, seventeenth and eighteenth centuries was one of the most efficient means of imparting a knowledge of Anatomy; but why should we in the twentieth century attempt to teach descriptive anatomy in the lecture room when the laboratory offers opportunities for more enduring and utilizable instruction? What does it advantage a student to listen to descriptions of organs or regions, be the lecturer

never so gifted with eloquence, when he can find in his text-books equally lucid descriptions of the same parts which he may study at his leisure. For just as the part of formal demonstrations is now taken by our laboratory courses so the part of the formal lecture is much better played by our text-books and atlases, and I believe that as far as descriptive anatomy is concerned, most of us, out of our own experience, are ready to echo Darwin's opinion, already quoted, that there are no advantages, but many disadvantages in lectures as compared with reading.

Perhaps I may be thought to be tilting with wind-mills in thus criticizing a method which many of us have long ago forgone; but many medical schools of this continent, either from force of circumstances or from conservatism, still cling to the formal lecture as a means of instruction. If one takes the trouble to look over a list of the number of hours devoted to Anatomy in our Medical Schools sufficient proof of this fact will quickly be obtained. For one will find one school advertising 220 hours of lectures and 290 hours of laboratory work, another 360 lecture hours and 324 laboratory hours, another 220 lecture hours and 230 laboratory hours, another 278 and 276, and another 435 and 334, another 287 and 180, and so on.

Just think of it! Two hundred and eighty-seven hours devoted to lectures and recitations and only one hundred and eighty to actual work in the laboratory. Here is mediævalism rampant indeed, and such a course of instruction one might expect to find mediæval in substance as well as in form.

But again I do not desire to be understood as advocating the abolition of lectures. For like demonstrations they have a part in our modern methods, and in certain departments of Anatomy they are almost indispensable. They should, however, be regarded as of secondary importance compared with the work in the laboratories, which it should be their function to elucidate and correlate. It is the formal lectures on descriptive anatomy that I condemn as unnecessary or even worse since they occupy valuable time that might well be turned to better purposes.

I have referred to the thoroughness with which our modern text-books of Anatomy treat the descriptive portion of their subject. But

are these text-books quite suited to the needs of the students? Is there not some conservatism still lingering about them and interfering with their proper adaptation to the purpose they have to fulfil? The standard set by Vesal's *De fabricâ* made thoroughness the keynote of text-books of Anatomy, and no minutiae of observation or theory were too trivial for record by the post-Vesalian anatomists. And most praiseworthy was the attention which the anatomists of those early days devoted to detail, and no less desirable is it that the anatomists of to-day should continue to be actuated by the same spirit of thoroughness. But should the student just entering upon the study of anatomy be compelled in the space of a couple of years to master the multitude of details accumulated by many generations of skilled and zealous anatomists? It seems to me a preposterous idea, and yet we place in the hands of our students, as guides and standards, ponderous volumes so replete with minute description that it is deemed beyond the powers of a single mortal even to write upon all portions of the subject, much less to master them, and so a number of collaborators is selected, each of whom devotes himself to the elaboration of a small section of the book. And yet what one man, even though he be a professional anatomist, is not considered capable of presenting with sufficient detail, the unfortunate student is expected to master in two short years. And not only must he become filled with the combined wisdom of half a dozen anatomists, but he must at the same time absorb and digest the learning and opinions of a similar number of physiologists, to say nothing of bacteriologists and physiological chemists. We seem to act on the principle that a student is a poriferous organism and the more thoroughly we immerse him in anatomical details the more of them he will absorb. This may be the case, but the absorbent powers of even a sponge are limited and, when taken from the water, it will gradually lose the moisture it has absorbed during its immersion and, furthermore, a very little pressure from without serves materially to hasten the dehydration. We do not want water-logged students, nor, if I may be allowed to change the metaphor, do we desire as the product of our teaching men who wander aimlessly in an undergrowth of details, unable to see the blazes on the trees which indicate the trail.

It is a painful sight to see a student, guided by his text-book, endeavoring to store up in his cortical cells a memory of the distribution of the peripheral nerves and their so-called anastomoses, and absolutely lacking any knowledge of the principles which govern the distribution of these structures. It may be said that it is the duty of his instructor to give him that fundamental information, and undoubtedly it is; but the point is that the instructor who endeavors to fulfil his duties in this respect finds himself seriously handicapped by the prominence given in the text-books to details and the perfunctory treatment afforded fundamental principles. The conception of Anatomy which the average student obtains from his text-book is that it is an immense collection of facts, and these facts must in and for themselves be mastered. He has neither time nor energy left for attention to what seem to him merely incidental and purely academic theories, and devotes himself to storing up in his mind a mass of facts, more or less isolated, and although it cannot be said that they are all without rhyme, yet they are for him all without reason. And, unfortunately, the text-books are not alone to blame for this erroneous conception of Anatomy; too often it is reinforced and fostered by the examiners whose ordeal the student must undergo and, what is even sadder, by his clinical teachers, both of whom assume that in his primary studies he should have mastered every detail of Anatomy, and severely criticize his instructors when they find that he has failed to achieve the impossible.

Surely the situation demands serious consideration. If our medical schools are to turn out men imbued with the scientific spirit, the spirit of progress, we, as instructors, must avoid as the deadliest of enemies to the fulfilment of our aims, everything that tends toward empiricism. And the methods now under condemnation lead nowhere else. The brilliant and fecund school of Anatomy at Alexandria was supplanted by the school of the Empirics, and the ideas which led to this condition, so disastrous to the progress of Medicine, were the same as those we not unfrequently hear advanced to-day by men who delight to call themselves practical. If we devote our energies to the graduation of adepts in the art of Medicine, ignorant of the sciences upon which that art must rest, we are failing

in our duty; and, similarly, if we overload our students with the facts of Anatomy, without giving them the scientific bases which make the facts intelligible, we are placing their feet upon the high-road to empiricism. I am convinced that the primary aim of the course of Anatomy in our Medical Schools should be to impart to the students by observation and deduction the fundamental principles of Anatomy, and that the minutiae of detail, when these are necessary for the proper understanding of special clinical problems, should be supplied in later years when the student comes face to face with the problems. In his primary years the student is incapable of appreciating the significance of such details; they are learned, if at all, by rote, and frequently, alas! solely because a knowledge of them may be demanded by an examiner. If, however, he has been grounded in the fundamentals of Anatomy in his primary years, if his anatomical instruction has been *teres atque rotundus*, he will be in a position under the guidance of his clinical teachers to add the third quality and make it also *totus*. But this desirable conjunction will be possible only when the arbitrary disjunction which now exists between the primary and the clinical courses of the medical curriculum is abolished, and the student is made to feel that his primary studies are not as a tale that is told when he has passed his formal examinations in them, but are really living, essential principles which will vivify and illuminate his clinical studies.

But my criticism of our text-books has led me into a discussion of a subject too great for adequate treatment on the present occasion. I had intended to complete my catalogue of conventionalities by calling your attention to a few special examples, not quite so ancient in origin, perhaps, as those already referred to, but still old enough to have "fallen into the sear, the yellow leaf." And yet they pass from one edition into another of our text-books, and, doubtless, are being taught to many students today just as they were taught to the generations to which their fathers and grandfathers belonged. I cannot trespass on the time of the Association to discuss the origin of these decrepit statements, which, like the barren fig-tree, cumber the ground, and must content myself with a mere mention of some of them. It is quite evident to even a casual observer that the

posterior wall of the sheath of the rectus abdominis is thinner in its lower than in its upper part and the transition from one part to the other, is, as a rule, quite abrupt, forming what we term the *linea semicircularis* or the fold of Douglas. But why should we be so conservative as to obscure this simple fact by attaching to it a theory concerning the aponeurosis of the internal oblique, stated as part of the fact? We but give the student an altogether erroneous conception of fasciæ and aponeuroses, leading him to regard them as comparable to a Butterick pattern, gored and gusseted, shirred and snipped until it fits into place, now splitting, now uniting, now passing behind and now in front of a muscle, and altogether resembling rather a product of the tailor's art than the outcome of the laws of natural growth.

And why should we be obliged year after year to explain that the saphenous opening—let me use this nomenclature only to condemn it—is not an opening, and this because some text-books continue to describe the fascia lata as having a pubic and an iliac portion, lying at different levels and, by their union, bounding what from the description must be an opening in the fascia? And, finally, surely our knowledge of the structure of the cranial sympathetic ganglia is sufficiently established and sufficiently old to lay open to condemnation the perpetuation in some recent text-books of the time-worn three-root theory, which merely obscures the true significance of the ganglia.

Numerous other instances of a similar nature will undoubtedly occur to you, but I think I have sufficiently demonstrated that, notwithstanding the wonderful progress Anatomy has made in the last half century, it is still groaning beneath a load of anachronisms, both general and particular. Darwin opened up for us a new field which we have diligently cultivated, but we cling to a sad extent to the ancient methods of disseminating the products of our toil. We have kept adding new material to our ancient garments, until the doublet and hose in which we set out have become things of shreds and patches, grotesquely unsuitable as a modern garb. Is it not time to consign them to the museum of mediæval costumes and don more serviceable modern habiliments?

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THE PRESENT POSITION OF THE THEORY OF AUTO-REGENERATION OF NERVES.

BY

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The controversy on nerve regulation as in the case of most scientific subjects has been marked by the repeated declaration that a disputant had attacked the views of an opponent before he was fully cognizant of the exact opinion the opponent was prepared to maintain. Cajal and other supporters of the central regeneration theory have repeatedly declared that their views have been incorrectly stated and their experiments misinterpreted. Bethe and those who hold similar opinions have never ceased to demand that before the autoregeneration theory be attacked the exact hypothesis on which it is based should be clearly recognized. It has repeatedly been stated that misinterpretations of this kind have been especially marked in American and English writers, and as they have chiefly attacked the theory of autoregeneration, Bethe, the most able exponent of this theory, has constantly asserted that his position has been misunderstood and misrepresented. It would therefore seem well to review the present position of the autoregeneration theory.

There are obviously three distinct views which might be held in regard to the regeneration of a sectioned nerve.

(1) That the regeneration is altogether from a central source; that is that the new axis cylinder grows out from a central or nutritive cell; and, in connection with it, the entire nerve fiber re-forms independent of any aid from the degenerated remnant in the peripheral stump.

(2) That regeneration of the nerve fiber is entirely peripheral, being renewed from what remains of the old nerve fiber and independent of a central connection.

(3) That the central and peripheral stumps each play an assisting part in the formation of the new nerve fiber.

In regard to the first view it has never been disputed and is easily demonstrated that outgrowth occurs at the central end. The dispute has been in regard to how far this outgrowth may extend, the purpose and outcome of it. There are no upholders of the central theory of regeneration who would claim that a sectioned nerve which has formed no connection with a previously existing nerve stump can grow indefinitely toward the periphery and re-establish its integrity. In short, regeneration cannot be entirely a central function, otherwise a sectioned nerve would always regenerate towards the periphery, whereas it is generally admitted that with no union with the peripheral stump the growth from the central stump cannot, in the adult at any rate, grow more than 3-5 cm.

There are few if any upholders of the theory that it is entirely peripheral, autoregenerative in the strict sense of the term. Such would necessitate the assumption that the sectioned nerve after having undergone degeneration is capable of reforming itself into axis cylinder and medullary sheath independent of any central influence. It is fully recognized that in the adult no nerve fiber ever reaches maturity unless it is attached to its own or some other similar central connection; accordingly some central influence must be assumed. It must be clearly recognized that most, if not all of the recent writers (Bethe among others) in support of the autoregenerative theory, use the word "autoregeneration" in a restricted sense, and in its restricted sense it is used in this paper and defined on a subsequent page.

It is obvious therefore that all are agreed that under ordinary circumstances some connection must be made between peripheral and central stumps for the nerve to regain its anatomical and physiological entirety. So most of the present-day controversialists must be classed as upholding the third view in a more or less modified form. The divergence of opinion depends on the views which are held in regard to the parts respectively played in the regeneration by the central and by the peripheral stump.

On the one hand we have the claims of the outgrowth theory that the new axon springs from a central nutritive cell; that it grows out

from the peripheral end of the central stump to the central end of the peripheral stump; that in the whole of its peripheral course it is derived from this source of origin; that attracted to the degenerated peripheral stump the outgrowing fibril utilizes the stump as a serviceable pathway towards the periphery and possibly finds in it a source of nourishment. Supporting this view Cajal (1) maintains that degeneration leaves the neurilemma whose mission it is to secrete and place at liberty a chemotactic substance capable of attracting young axons growing out from the central stump; and moreover the neurilemma so left may assist in the nutrition and growth of the fibril which has been so attracted into its protoplasmic sheath. Among English writers Mott (2) also asserts his view and emphasizes the important part played by the neurilemma cell in the degenerated stump. "The activity of the neurilemma cells is related to successful repair of a divided nerve, for where neurilemma does not exist, *e. g.* in the central nervous system, removal of degenerated myeline is very slow and regeneration does not occur."

On the other hand, while the supporters of the autoregeneration theory acknowledge that there is constantly some central influence at work, they regard this central influence as limited to the supply of some form of energy which enables the peripheral part to grow to the maturity of a fully developed nerve fiber. They claim that the peripheral stump itself after degeneration contains all the constituents requisite for growth and that what it lacks is the power to develop these to maturity in the adult animal. There is acknowledged a certain amount of growth from the central towards the peripheral stump, but it is claimed that there is also, though to a less degree, a growth from the peripheral towards the central stump, and that the obvious purpose of such growth is to reunite the sectioned ends. They deny a central growth of axon into the neurilemma cells in the peripheral stump.

Supporting this view Bethe (3) maintains that the new nerve fibers arise in the peripheral stump, after union with the central stump, growing from the Axialstrandfasern which remain as the so-called terminal stage in the process of degeneration. He found in experiments on young animals that, independent of any central connection,

the degenerated nerve can regain anatomical entirety, axis cylinder and medullary sheath, and restoration of physiological function. He claims that this is due to the recuperative power still present in the cells of the young animal. In the adult this recuperative power is deficient and central connection is requisite to enable the peripheral part to reach the stage of anatomical and physiological maturity. What the central end supplies is not determined, it may be of the nature of a ferment or some form of energy, but there are no ingrowing axons.

It is obvious that both parties in the controversy assign important functions to the central and to the peripheral stump. But their differences are great and relate to the origin of what one regards as the essential constituents of the nerve fiber—the axis cylinder and the medullary sheath. It may be well here to briefly review the various stages of degeneration which have been histologically demonstrated by various authors, *e. g.* by Howell and Huber and by v. Bugner, and state briefly the chief points which are in the main undisputed.

I. The first stage of degeneration usually described is a coarse granulation of the axis cylinder and a breaking up of the medullary sheath at the intersegmental lines of Lantermann. There is, however, a prior stage apparent only in the axis cylinder, marked by its becoming finely granular and by an alteration in its chemical constitution. A little later in this stage there is seen a smaller fragmentation of the myeline and increase in the size of the neurilemma nucleus and of the protoplasm around it—the axis cylinder now being broken up and very coarsely granular. The breaking up of the myeline is very irregular; it is more advanced near the central end of the peripheral stump; and in the internodal segment it is usually further advanced near the nucleus. The increase in size of the nucleus is followed by its multiplication by mitosis—so that one finds more than one nucleus in the internodal segment.

II. The second stage in the process of degeneration is associated with the disappearance of the myeline. The internodal segment is now a homogeneous mass lying in the old, more or less collapsed, neurilemma sheath. In it are many nuclei often in pairs and showing signs of mitosis. There is no sign of axis cylinder. It must, however,

be noted that the old myeline may remain in some of the sheaths for a very long time.

III. Closely associated with the preceding changes is the third stage in which there is increase of protoplasm around the nucleus. At first the nucleus lies in a spindle-shaped homogeneous mass of protoplasm which gradually increases and the spindle-shaped homogeneous masses become confluent. Thus we have the old neurilemma sheath filled with a continuous band of protoplasm (*Bandfasern*), differing from ordinary cytoplasm in that it is non-granular and stains very badly with ordinary protoplasmic stains, resembling in this respect embryonic fibers. Later the protoplasm is found to stain more distinctly at the periphery of the cell while the center remains clear. At this stage the nucleus lies under the neurilemma lying on rather than embedded in the protoplasm. These constitute the *Axialstrandfasern*.

These three stages are usually called the "stages of degeneration" and are to be observed in all peripheral stumps after break of continuity with the central connection. They appear independent of the occurrence of any union between the central and peripheral stumps—though union hastens all the stages. There is in the main agreement in regard to the morphological findings, though some maintain that at the end of the third stage fine fibrillation can be discerned in the protoplasm adjacent to the nucleus; but this has been so often disputed that one cannot regard it as definitely settled. Yet it may well be doubted if one is justified in regarding the third stage as belonging to a degeneration process. Apart from the morphological changes which appear to justify the statement that in the third stage there is an obvious process of regeneration, the ultimate outcome of this stage is a tissue which shows some specific nervous qualities, for example affinity for sensory or motor nerves corresponding to the kind or nerve from which it was originally derived—sensory or motor. If one does not acknowledge some amount of specificity in the *Axialstrandfasern* it would be difficult to explain why reunion will not occur between a motor and a degenerated sensory nerve or vice versa; or further why it is impossible to have union of an efferent post-ganglionic nerve to a motor nerve (4). Bethe (5) has recently pointed out this further similarity between the axial strand fiber and the

normal nerve, namely that if the axial strand fiber be cut there follow changes in its peripheral end analogous to those in a sectioned normal nerve—irregularity in outline and increase in size and number of nuclei.

While the preceding stages are in the main undisputed the succeeding stages in the repair of the nerve are the subject of very different opinions. It is generally acknowledged that in the adult the regenerative process in the peripheral stump, not connected with the central stump, stops at this stage. Should reunion have been brought about there follows the stage associated with the reappearance of axis-cylinder and myeline. It is agreed and easily demonstrated that nerve fibrils spring out from the central stump, but it is not generally acknowledged that these are the fibrils which are ultimately found within the old neurilemma sheath. Bethe asserts that the first union between the sectioned ends is by means of connective tissue along which the central outgrowing fibrils pass; that these outgrowing fibrils from the central stump meet corresponding, generally less pronounced, outgrowing fibrils from the peripheral stump, and so there is formed a union between the separate ends of the nerve, and that the new axis cylinders arise in the Axialstrandfasern from the fibrillation which v. Bugner and others describe as being present at the end of the third stage.

The most able disputant of these views has been Cajal, who claims that the outgrowing fibrils can be definitely traced into the old neurilemma sheath. The difficulty of determining this point has been largely due to the absence of definite staining reagents for the axis cylinder. The method most used is that of Cajal in one of its various modifications. The efficacy of this method is disputed, though the objection that by it only small pieces of tissue can be used, seems irrelevant as with small pieces it may still be possible to trace a nerve sufficiently far to see it going into the old neurilemma sheath. A more serious objection is the twisting and shrinking which the tissue undergoes, and that the fibers stained depend on the particular chemical condition at the time.

As a result the question has been largely decided on the presence of the medullary sheath in nerves which are physiologically demonstrable to be not united with a central connection.

The reappearance of the myeline is closely associated with the reappearance of the axis cylinder. The exact point within the old neurilemma sheath at which it is first observed, is not agreed upon; according to Cajal it is first seen at the periphery of the cell, according to v. Bugner near the nucleus. However this may be, the myeline increases in amount and the detached parts get united by slender bands of myeline but remain separated at the future nodes of Ranvier. At this stage the numerous nuclei disappear and a new neurilemma with one nucleus is formed, probably from the protoplasm which surrounded the myelinated tube.

The points in dispute are therefore in regard to the origin of the axis cylinder and the medullary sheath. Can these appear in the old neurilemma sheath independent of a central union? Does the axis cylinder which there appears spring from the central stump? Whether these points can be decided from a purely histological standpoint with the methods at present at our disposal is open to doubt. The brilliant work of Cajal and others is not altogether convincing; one can admit outgrowth and subdivision of central axons, but the difficulty of following these sufficiently far to be assured that they definitely enter the old neurilemma sheaths seems to be surrounded by such great difficulties as to require substantiation by other methods.

As a result the problem has been attacked more from the combined physiological and anatomical standpoint than from the purely anatomical, and with much justification, since the ultimate test of a normal nerve is its physiological activity. The question raised has been what can the peripheral nerve undoubtedly separated from its nutritive centre accomplish towards regeneration under conditions which can be regarded as most favorable, namely in young developing animals? It is agreed that in adults a distance of 3-5 cm. renders union improbable, if not impossible, and the peripheral stump never passes beyond the Axialstrandfasern stage. But it is maintained by the upholders of the autoregeneration theory that in the young animal with a distance very much greater and when no connection can be shown to exist between the central and peripheral stump an axis cylinder and medullary sheath may form. This leads to the essential point of the controversy, namely, what conditions must be fulfilled so that one can

definitely say that no connection exists between the peripheral stump and the central stump or central nervous system? Obviously there must be demonstrated physiological loss of irritability and conductivity associated with anatomical degeneration, followed by a restoration of the recognized anatomical constituents and of the physiological function, while at the same time it is demonstrated that union of the peripheral stump with any central connection cannot have taken place.

In carrying out these investigations young animals must be used. Bethe prefers, and almost exclusively uses, dogs of the age of four to six weeks. The demonstration of the physiological loss of function and of the anatomical degeneration has never been difficult; after two or three weeks the nerve is exposed, examined physiologically and a piece removed for histological examination. In many of the cases the nature of the operation, the obvious loss of function, and the results are sufficient to justify the assumption and render it unnecessary in every case to repeat the intermediate examination.

But when one desires to show that no union has taken place between the sectioned ends we have to encounter the additional difficulty of determining whether or not union has occurred with another nerve. Bethe's experiments are performed so as to leave the peripheral end as uninjured as possible and to remove as much of the central stump as he can; if necessary, the whole of it with the spinal attachments. He prefers the N. ischiadicus because of the advantages it offers of definite distribution and few anastomoses. It is unnecessary here to name the numerous experiments he has devised and performed in order to isolate the peripheral stump. A typical one may suffice. He severs the nerve in the popliteal space through a small incision; exposes it again at the Foramen ischiadicum and pulls the lower end up and out and finally tears the nerve away from its spinal attachments with ganglia and roots. Not in all cases, but in a large proportion, he gets signs of autoregeneration tested physiologically and examined anatomically. But even in young animals the power to regenerate under such conditions is less marked than if the nerve be reunited.

One cannot but acknowledge that the greater number of investigators, experimenting on much the same lines, have formed an opinion

<i>Date of testing.</i>	<i>Stimulation of peripheral end.</i>	<i>Stimulation of central end.</i>	<i>Microscopical findings. (Note 1.)</i>
Dec. 18. Dog A.	N. peroneus com. = O. N. tibialis = +.	N. ischiad. showed evidence of union between N. tibialis and N. ischiad.	An occasional n. fiber seen. No recently degenerated fibers. Numerous med. fibers. No recently degenerated fibers seen.
Jan. 17. Dog B. (Note 2.)	N. peroneus com. = +. Slight contraction of peroneal muscles and very slight eversion of foot. N. tibialis in left head of M. gastrocnemius = +.	N. ischiad. on peroneal = O. No eversion. N. femoral, N. obturator in abdomen on peroneal muscles = O. N. ischiad. gave contraction of M. gastrocnemius at lower end near Tendo Achilles more apparent to right side.	Medullated fibers but very few compared with normal. No sign of degenerated fibers. Medullated fibers.
Jan. 24. Dog C.	N. peroneus com. = O. N. tibialis on M. gastrocnemius = +.	N. ischiadicus action on peroneal muscles = O. Nn. ischiad., obturator and femoral on M. gastrocnemius = O.	Only one or two scattered fibers in N. peroneus com. A large number of medullated fibers in N. tibialis, though fewer than normal.
Feb. 28. Dog D.	N. tibialis = O. N. peroneus com. = O.	Nn. ischiad., femoral, obturator on muscles below point of section = O.	In N. tibialis and N. peroneus com. only occasionally medullated fibers seen. No recently degenerated fibers.

directly opposed to that of Bethe. To quote only a few, one may mention that Langley and Anderson with cats and rabbits, Mott and Halliburton with adult monkeys, never got positive signs of regeneration except when connection could be demonstrated.

I take from my own experiments the following four cases, the last of a series used to test Bethe's conclusions and which are a fair sample of the results I have obtained.

June 6, 1907; the left N. ischiadicus was sectioned in four dogs six weeks old. The results were as follows.

(O = no result from stimulation; + = muscular contraction from stimulation.)

Result in four cases: Negative 1, Dog D, Positive 1, Dog C.

Union between central and peripheral stumps 2, Dogs A and B.

(NOTE 1.) Pieces were removed from the normal nerve, and from both the central and peripheral end of the sectioned nerve and placed in osmic acid; other pieces were placed in Marchi to test whether or not recently degenerated fibers were present. (6 and 7.)

(NOTE 2.) Macroscopically there were seen several filaments sprouting into the scar tissue from the central stump just external to its entrance into M. gluteus maximus (see method of operation below). These filaments could be traced through the scar up to the peripheral stump. Microscopically they were found to contain medullated fibers. So though physiological union could be demonstrated only between the N. ischiadicus and the N. peroneus communis there existed undoubted anatomical union between the two stumps.

The following more detailed account will suffice to make the methods employed evident.

June 6, 1907. Dog six weeks old. Through a small incision the left N. ischiadicus was exposed above the popliteal space and cut superior to its division into the N. peroneus communis and N. tibialis. Care was taken to injure the peripheral end as little as possible and in the subsequent manipulations the peripheral stump was untouched. The N. ischiadicus was now exposed by a small incision just above a line joining the Trochanter major with the Tuber ischiadicum. Its lower end was pulled out and about $1\frac{1}{2}$ cm. removed. By means of catch forceps thrust through the Gluteus maximus the central stump

which had been left sufficiently long, was seized and fixed in this muscle with ligatures. The wounds healed without suppuration.

January 24, 1908. The dog had grown well and was in good health. Local sores had developed on the left foot, but were now quite healed. The animal has no control of leg under knee and is perfectly insensitive to touch or pricking with pin. Under an anesthetic the N. peroneus communis was exposed at upper end of fibula. The nerve was flat and lacked the normal glistening appearance. Stimulation with faradic current was negative. (One dry cell was employed which had been in use for some time.) The N. tibialis, exposed in popliteal space inferior to old scar wound, was glistening in appearance but flatter than normal. Stimulation gave distinct contraction of M. gastrocnemius at 21 cm. The N. ischiadicus was exposed at the Incisura ischiadica; stimulation gave contraction of Mm. biceps femoris and semitendinosus but not of M. gastrocnemius. The lumbosacral cord was exposed in the abdominal cavity and the femoral and obturator nerves stimulated with no resulting contraction of M. gastrocnemius. Stimulation of other nerves of the lumbosacral cord gave no result on M. gastrocnemius. Surface conduction was eliminated in the N. tibialis; the nerve was tested when well raised and a damp silk ligature effectually stopped conduction at 21 cm. Microscopically: The number of medullated fibers in N. tibialis, though very considerable, was small compared with normal. Occasionally one could recognize degenerated nerve fibers by small pieces of myeline which were to be seen scattered about in small amounts in the neurilemma sheaths. No recently degenerated fibers were seen. Only a few scattered fibers were found in the tissue between the central and peripheral ends; there were no strands of fibers as in dog B. (See also Bethe, *Neue Versuche über die Regeneration der Nervenfasern*, Arch. f. d. ges. Physiol., 1907, p. 427.)

With such a series can one say that all possible sources of contamination are excluded? It would appear to me that cases do occur, *e. g.*, Dog C, in which with our present knowledge such a claim may be made, cases in which we have physiological and anatomical proof of nerve regeneration where it could not be shown that the peripheral stump was in any way connected with the central nervous system.

But the weakness of the reaction in the peripheral stump together with the very marked diminution in the number of normal fibers present compared with that of the normal limb, the absence of distinct signs of recently degenerated fibers make ever present the lurking doubt that possibly some source of contamination had been overlooked.

To still further obviate such an error Lugaro (8) removed not only the nerve but carefully excised the corresponding spinal roots. Under such conditions he never got regeneration in the peripheral part left. I have no means of judging in what condition the animals experimented on by Lugaro were at the end of the required period. In the animals on which I have attempted to do a similar experiment the resulting marasmus was so great that they either died or were killed within two months. With animals in such a condition the objection might well be raised that a negative result might easily come from the general condition being far from normal. Bethe (9) however succeeded notwithstanding the diminution in growth and the extreme emaciation in keeping an animal alive for the desired period and he claims a positive result.

So the controversy stands. The teaching of the autoregeneration theory as enunciated by Bethe is perfectly clear, namely, that the Axialstrandfasern under some influence, perhaps fermentative, from the central fibers can differentiate to normal fibers; and that in young animals this differentiation may go on without central influence. In all cases by union the peripheral borrows fresh strength from the central fibers.

Though the result has not been to settle the question, one must acknowledge that the preponderating opinion is opposed to the possibility of regeneration of axis cylinder and medullary sheath apart from central union and central outgrowth. There has, however, resulted a clearer conception of the importance of the neurilemma and of the part it plays in at least preparing the peripheral stump for the regenerating process. Further it is difficult to escape the conclusion that the degenerative process in a sectioned nerve irrespective of union with the central stump passes on to a stage (Axialstrandfasern stage) where a certain degree of specificity is marked and which one may well regard as a stage in a regenerative process.

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STUDIES IN THE ANATOMY AND PHYSIOLOGY OF THE HIP-JOINT.

BY

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WITH 5 FIGURES.

I.

THE ILIO-TROCHANTERIC LIGAMENT.

In the following study is presented the result of a search begun while the writer was a student in Waldeyer's Institute nearly ten years ago. A well marked example of the ligament about to be described was worked out and brought to the attention of Prof. H. Virchow. He encouraged repeated dissections in order to determine its constancy, and it was to him that I owed the access to abundant material both human and comparative, for which kindness I am glad to express my appreciation. Since returning home the study has been continued in the dissecting room of the University Medical College.

The name, ilio-trochanteric, has been adopted because of the origin and insertion of the ligament and because of the resemblance in location to a muscle of that name in some of the lower animals, to which Professor Virchow suggested it might present some philogenetic relationship. Ilio-pretrochanteric ligament would be a more exact name. The ligament arises from the edge of the acetabulum below the reflected head of the rectus (but entirely independent of it) from an area from 1.5 to 2 cm. broad. It forms a band from 7 to 14 mm. broad and from 3 to 8 mm. thick, which passes outward and at $1\frac{1}{2}$ to 2 cm. from the trochanter becomes intimately blended with the tendon of the gluteus minimum and is inserted in the anterior surface of the great trochanter immediately below the insertion of the tendon of that muscle. The insertion is entirely independent of the vastus lateralis. (Fig. 1.)

Ligaments resembling the one above described have been noted by various authors as of occasional occurrence. Morris states in his Textbook, second edition, p. 247, regarding the ilio-trochanteric band: "Between the ilio-femoral and ischio-femoral bands the capsule is very

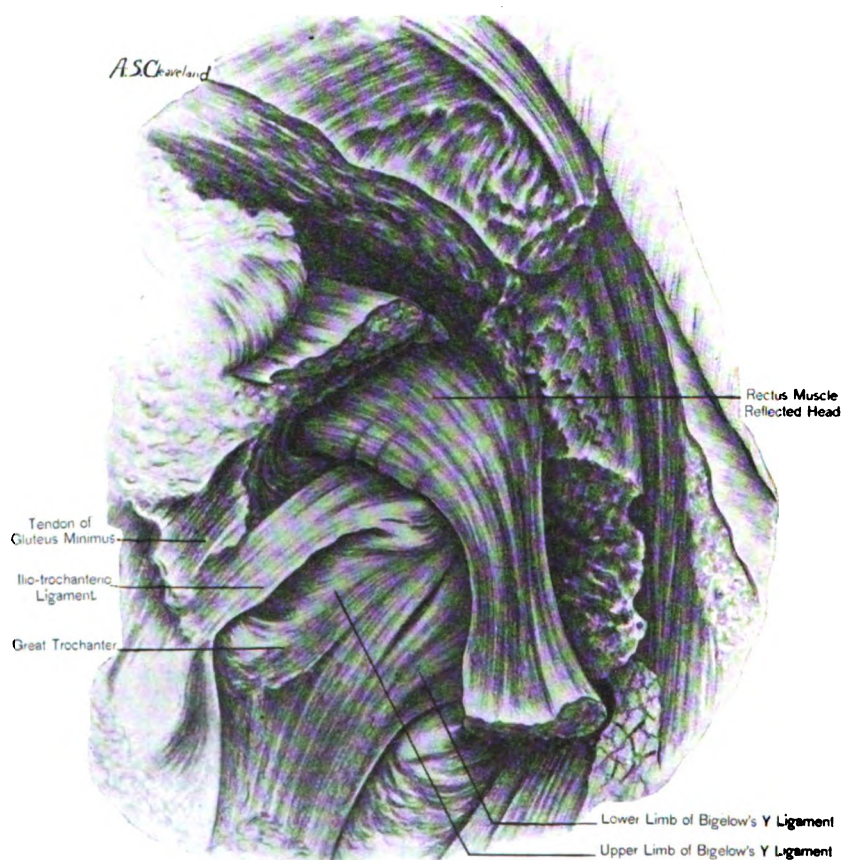


FIG. 1.

strong, and with it here, near the acetabulum is incorporated the reflected tendon of the rectus, and here also a triangular band of fibres runs downward and forward to be attached by a narrow insertion to the ridge on the front of the border of the great trochanter near the

gluteus minimus (the ilio-trochanteric band).” I am unable to gain neither from the description nor from the cut the relation of this band to the ligament which I have here described.

He figures also (Fig. 237) a band which corresponds to the ligament I here describe. He says of it “the tendino-trochanteric band passes down from the reflected head of the rectus to the vastus externus.” The figure shows it as being inserted at the upper anterior surface of the great trochanter where he says the ilio-trochanteric ligament is inserted. In reference to this band, Piersol states that “Morris describes a band on the upper anterior aspect

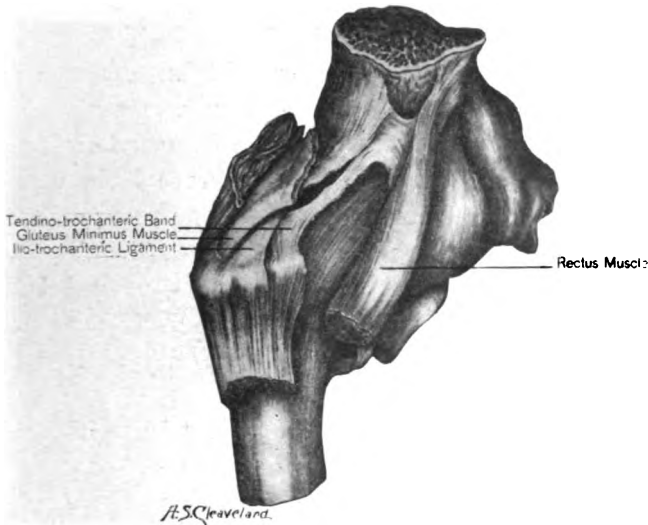


FIG. 2.

passing between the reflected tendon of the rectus and the highest region of the vastus externus, which is sometimes very strong but in our opinion inconstant.” This tendon I have noted but twice in more than a hundred dissections. In Fig. 2 it is shown together with the ilio-trochanteric ligament. This figure was drawn from a formalized and dried specimen. The ilio-trochanteric ligament in this drawing is very small, perhaps because of the presence of the tendo-trochanteric band, and it is atypical in its origin and also in its insertion in that it is blended with the origin of the vastus lateralis.

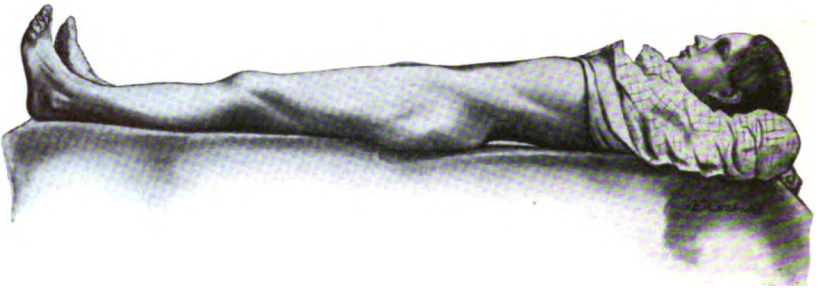


FIG. 3.

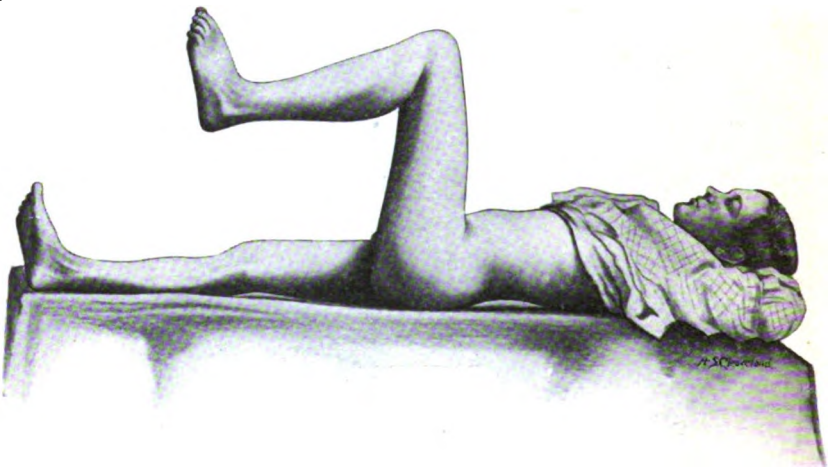


FIG. 4.

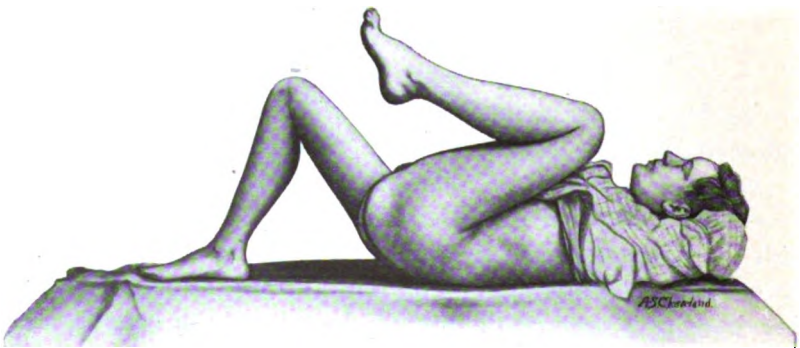


FIG. 5.

The ilio-trochanteric ligament here described is not a part of the Bigelow Y ligament as the American textbook implies. I conclude this because there is a pad of loose connective tissue and fat between the ilio-trochanteric ligament and the capsular ligament and occasionally a bursa is found between the pad of fat and the ligament. The Y ligament of Bigelow remains after the ilio-trochanteric ligament is removed.

I have examined more than a hundred hips without a failure to find it. In two cadavers it was membranous, yet distinct as to origin and insertion. In the vast majority of instances it represents a strong band, as shown in Fig. 1.

II.

RANGE OF MOVEMENT IN THE HIP-JOINT.

The textbooks are a unit in declaring that the movement of the thigh upon the pelvis is nearly 180 degrees and that flexion of the thigh is limited by the contact of the muscles of the thigh upon the abdomen. While attempting to determine the function of the ilio-trochanteric ligament this statement, so universal in the textbooks, came to be seriously questioned.

Fig. 3 shows a drawing of a boy of seventeen lying prone upon a board. It will be noted that when the leg is in contact with the board the lumbar curve is marked. The spinous processes were 4 cm. from the board. When the thigh was brought to a right angle to the plane of the board upon which the individual lay (Fig. 4) the movement of the head of the femur in the acetabulum suddenly stopped. With the relaxed limb (preferably made under an anesthetic) the exact point of stoppage could be accurately determined. When the flexion was continued beyond this point it was attended by a rolling of the pelvis upon its transverse diameter which was made manifest by the obliteration of the lumbar curve and the raising of the sacrum from the board (Fig. 5). This simple manipulation demonstrated, therefore, that the flexion beyond a right angle is dependent upon motion in the spine and not in the hip, and obviously it is incorrect to ascribe to the hip-joint a motion which takes place in the lumbar spine.

The amount of motion actually taking place in the hip according to the above methods of measurement is about 100 degrees, depending chiefly on the age of the individual. In children it is greater, in old persons frequently much less. The boy (aged seventeen years) from whom the cuts were made presented a range of 100 degrees, which may be taken as an average for young adults. In a series of medical students, measured with a special instrument made for this purpose, this was found to be quite constant.

What factors go to limit the motion of the hip-joint seems difficult to determine. That the extension is limited by the dense anterior capsule, as the textbooks say, seems quite clear; but what limits the flexion is difficult to determine. When the angular ligament is severed a slight additional flexion is secured, but the ilio-trochanteric and the upper portion of the capsule soon offer resistance. When these are severed a considerable additional flexion is obtained. These ligaments then may be tentatively said to limit the flexion of the hip-joint. A severance of all the ligaments is necessary before the range of motion can be made to approximate the 180 degrees as demanded by the "anatomies."

Received for publication, December 25, 1908.

AN INJECTING FLUID FOR PRESERVING CADAVERS FOR DISSECTION.

BY

WILLIAM C. LUSK.

*From the Anatomical Department of the New York University and Bellevue
Hospital Medical College.*

Experimental work on the preservation of cadavers for dissection has been done in this country by Keiller,¹ Mall² and Souchon.³

Keiller uses a preserving fluid containing formalin, carbolic acid and glycerin. Mall uses carbolic acid, glycerin and alcohol. Souchon's formula for embalming bodies for the dissecting-room comprises arsenious acid, formalin, carbolic acid, glycerin, alcohol, and creosote. In here voicing the use of carbolic acid, it is of interest to recall that the valuable deodorant and preservative properties of this chemical in the preservation of cadavers were first recognized by Rüdinger in the early seventies, and as well that carbolic acid has been used continuously at the Johns Hopkins since the opening of the Medical School in 1893.

During the years 1899 to 1902, when the writer had charge of the dissecting-room at the New York University and Bellevue Hospital Medical College, he made experimental studies on the preservation of the cadavers for dissecting-room work, with the intent of producing a material that would possess firmness with pliability, and that would not readily decompose or dry up during dissection. The following formula was the finished product of the experimentation, which filled all the requirements aimed for, and besides, when formalin was not added, preserved the bright red color of the muscles. The addition

¹Keiller. Phila. Med. Journ., 1900, p. 1248. Amer. Jour. Anat., II, 1902-03, Proceedings Assoc American Anatomists, p. vii.

²Mall. Johns Hopkins Hospital Bulletin, XVI, February, 1905.

³Souchon. Anatomical Record, II., 1908, p. 244.

of the two-thirds per cent. of formalin darkened the muscles somewhat.

Injecting fluid.

Glycerin	2000 c.c.
Carbolic acid, pure	500
Mix thoroughly with egg-beater, then add:	
Alcohol	2000
Mix thoroughly again, then add:	
Solution hydrosodium arsenite (made as indicated below)	3000
<hr/>	
	7500 c.c.

Mix the whole thoroughly and *let stand over night before use.*

For green bodies, *if desired*, may then add:

Formalin, two-thirds per cent (= about one-fourth per cent formaldehyd) (*not a necessity*)..... 50

7550 c.c.

Mix again thoroughly and *let solution stand at least three or four hours more before use.*

The solution of hydrosodium arsenite is made as follows:

Arsenious acid (about 97 per cent pure).....	50 ounces.
Sodium carbonat. siccum	40 ounces.
Water	10,000 c.c.

Boil from two to three hours.

Bodies of 100 pounds require for preservation from 4000 to 5000 cc. of the injecting fluid, and for each 25 pounds additional weight of the body there should be added about 1000 cc. of the fluid.

This injecting fluid, or one made in all essentials like it, has since been used in the college dissecting-room for the past six years with eminent satisfaction. The fluid produces the best material for dissection when the instructions of the formula are adhered to with exactness. The use of carbolic acid as a preservative for anatomical material has the particular advantage that the bodies injected with it do not readily decompose, and consequently the atmosphere of the dissecting-room is not loaded with the gases of decomposition and there need be no unpleasant odor about the premises. The glycerin in the injection possesses the advantages, first, that in mixing the fluid it causes a ready solution of the carbolic acid, and second, after

injection into the body, it prevents rapid drying of the tissues. By its hygroscopic property it will take up sufficient moisture simply from a dampened fabric to keep the structures soft, thus doing away with any need for drenching the dissection with water, which procedure only dissolves out the chemical preservatives and thus aids decomposition.

Carbolic acid and glycerin in combination with alcohol in varying proportions are much used by medical schools for embalming cadavers. The writer in experimenting with this mixture found that while the above mentioned desirable properties of the carbolic and the glycerin held good, yet certain disadvantages were apparent. Thus the carbolic browned or blanched the muscle fibers, and seemed to destroy their tensile strength, making them readily frayable when picked with forceps. Also when used in the considerable strength of 33 per cent. the carbolic would numb the fingers of the dissector. The glycerin in this combination seemed to be the cause, probably from its hygroscopic action, of making the tissues, particularly the dependent ones, soggy with water.

The question arose how to utilize carbolic acid and glycerin in an embalming fluid in a way to reap their advantages and at the same time eliminate their objectionable features. The addition to a mixture of glycerin, carbolic acid and alcohol, of a solution of hydrosodium arsenite with a small excess of sodium carbonate in the proportions given in the above formula, finally gave the desired result. The wetting action of the glycerin on the tissue was offset so that the latter became quite free from excessive moisture, the muscles were firm and red, and the fasciæ of a normal tensile strength. The viscera were pliable and well preserved. The cut tissues of a freshly injected body would emit a slightly sourish odor which was characteristic of a well made injection.

The thorough mixing of the ingredients and the letting of the solution stand for 12 to 24 hours before use, are very important elements in securing the best result. The necessity for the thorough mixing is particularly for the purpose of securing an equable distribution in the fluid, of the carbolic acid which, if not evenly mixed, will produce brownish areas in the injected muscles. The formalin too when used should be well mixed since there is a very small quantity of it to be diffused throughout a large volume of fluid.

In explanation of the better result from letting the injecting fluid stand for some hours after mixing, the writer should state it as his belief that a chemical combination takes place between the carbolic acid in solution and the excess of soda carbonate, to form a carbolate of soda, and that a certain length of time for the complete conversion of the carbolic acid is required, so that if the solution is injected immediately after it is mixed, this change will not have had time to have fully taken place, and the unchanged carbolic acid then exercises its corrosive effect on the muscles. Whereas, with the carbolic acid converted by the alkali into the carbolate of soda, while retaining its power as a preservative, its ill effects on the muscles are counteracted. That a chemical change does take place between a mixture of glycerin, carbolic acid and alcohol, and a solution of sodium carbonate, is evidenced by the evolution of gas which takes place when these two liquids are mixed together. In further evidence that an alkali does in some way offset a destructive action on muscle fibers attributable to carbolic acid, it was found by comparing one body injected with a preserving fluid consisting of carbolic acid, glycerin and alcohol, made slightly alkaline with potassium carbonate, with another body injected with the same chemicals but made more strongly alkaline with the potassium carbonate. In the latter instance the muscle fibers were much stronger than in the former. It was also noted in the course of experimentation that where the injected muscle fibers had an alkaline reaction to litmus paper they were much firmer and less easy to fray when picked with forceps, than where the reaction was acid. In this connection it is an interesting fact that the reactions of both carbolic acid and glycerin are alkaline, while that of alcohol is acid as is also that of the tissues of the dead body. Thus it might be regarded possible for an alkaline reaction of the muscles to be brought about from the carbolic acid and glycerin in the injecting fluid, yet as a matter of fact when glycerin, carbolic acid, alcohol and hydrosodium arsenite were used in combination, the tissues seemed never evenly alkaline throughout the entire body unless a sufficient amount of sodium carbonate had been added in the making up of the fluid.

The need for letting the fluid stand before use after the formalin had been added, was demonstrated by the resulting greater toughening

of the fasciæ and skin and the hardening of the fat, which were not so apparent when this regulation was not observed.

In making up the injecting solution corresponding to the above formula, since glycerin is a ready solvent of carbolic acid, these two ingredients are first mixed together, the necessary flagellation of the liquids to effect the solution of the carbolic being best done with an egg-beater.

The necessity for the alcohol arises from the fact that this fluid thins the glycerin down so that the injection will flow freely from a reservoir through the arteries into the tissues of the cadaver. Also unless the amount of alcohol in the above formula equals that of the glycerin, the injecting fluid will be too thick to pass entirely out of the terminal arterial branches and, lodging in these, will obstruct the entrance into them of the starch injection.

The hydrosodium arsenite, besides being an excellent preservative, seemed to be the factor which enabled the muscles to retain their red color in the presence of the carbolic acid and which offset the apparent action of the glycerin to make the tissues soggy. The hydrosodium arsenite was made by boiling arsenious acid (As_2O_3) with sodium carbonate siccum (Na_2CO_3) or dry soda ash, in water for two or three hours. The ordinary carbonate of soda or washing soda, containing ten molecules of water of crystallization for each molecule of the salt, and therefore representing less of the salt than an equal weight of the dry soda ash, if used, should be calculated accordingly. On boiling the arsenious acid and soda together in water, it was found, estimating by atomic weights, that the acid would actually combine with but about one-third the quantity of soda that would be necessary to completely convert it into a triple sodium arsenite, so that the resulting product would be a hydrosodium arsenite, probably having for the most part the formula H_2NaAsO_3 . Thus it was found that about 14 ounces of dry soda ash would combine with 31 ounces of arsenious acid (or in the proportion of 22.6 to 50) to make a solution of hydrosodium arsenite having just the slightest possible amount of alkali in excess, or practically making a neutral solution. The prolonged boiling for from two to three hours was necessary to effect the combination of the greatest possible amount of

soda with the arsenious acid. The proportion of sodium carbonate used in the injecting fluid seemed to have a threefold influence, first, on the amount of moisture in the injected tissues, second, on the power of the arsenic to irritate the hands, and third, on the strength of the muscle fibers. Bodies injected with a nearly neutral hydrosodium arsenite solution in combination with glycerin, carbolic acid and alcohol were noticeable for the absence of all soggyiness of the tissues. The structures were dry and pliable and the color of the muscles was red, but there were two objections;—first, the muscle fibers were weaker than when more of the alkali was used, and second, especially objectionable was the severe arsenic irritation beneath the finger nails of those dissecting the bodies thus injected. The addition of a small excess of the sodium carbonate beyond what would combine with the arsenious acid solution, now remedied these two difficulties, the proportion used being sodium carbonat. siccum 40 ounces to arsenious acid 50 ounces. The tensile strength of the injected muscle fibers in the presence of this small excess of carbonate of soda is very much greater than that of living muscle fibers, the picking of the injected fibers with a thumb forceps requiring some considerable force to rupture them. In explanation of this the writer would state as his belief that the result is partly due, as already mentioned, to a transformation of carbolic acid into a carbolate of soda in which combination the carbolic supposedly no longer exerts its destructive action on the muscles, and also there may be besides a strengthening influence on the muscles, produced by the hydrosodium arsenite in the presence of an alkaline medium. With this added amount of carbonate of soda also the arsenic irritation beneath the finger nails was practically done away with. It was of interest to note that a considerable excess of sodium carbonate added to the injecting fluid, would reverse the evident drying action of the more nearly neutral solution, causing the tissues to be again very moist, so that for the sake of getting as dry a tissue as practicable, only enough soda to prevent finger irritation by the arsenic was used, which amount was found to be a little more than that needed to cause strengthening of the muscles.

An arsenate of soda, alkaline with sodium hydrate, was tried in combination with glycerin, carbolic acid and alcohol, the effect of

which seemed to be to produce generally wet tissues, and muscle fibres weak in consistence though of a good red color.

By the addition of the two-thirds per cent of formalin (one-fourth per cent formaldehyd) to the formula here advocated, it seemed particularly that the fasciæ were strengthened, the skin toughened, and the fat hardened. The muscles were darkened a little. Since formalin is evanescent it cannot have a long continued action as a preservative, so that the main purpose for its use would be the primary arrest of decomposition in green bodies. The formalin is however really not a necessary addition to the injecting fluid, since green bodies, many days dead, were injected without the formalin having been added and the injected tissues have shown a perfect arrest of decomposition and possessed the qualities desirable for good dissecting material. However, formalin is such a popular disinfectant for the arrest of decomposition and is so much used for the purpose of preserving anatomical and pathological specimens, that it is mentioned here to specify in what strength it can be used to the best advantage in connection with the injecting fluid here described. If formalin of a greater strength than about two-thirds per cent be added the fasciæ and skin will be found to have been unduly toughened so as to materially add to the labor of dissecting. It was noteworthy in one cadaver where an injection containing a considerable strength of formalin (probably 10 per cent) in combination with an arsenic salt was tried, that the muscles were made stiff, and at the same time lost all tensile strength, so that when the arms were raised upward the pectoral muscles tore across like paper. This is in keeping with the experience of Addison⁴ who, in advocating an injecting fluid comprising formalin, arsenic and potassium carbonate, the formalin being used in a strength of 5 per cent for its hardening effect on the body, notes that the muscles by this combination are "made brittle and are torn across in putting the body in the lithotomy position unless care be exercised." He adds, "For demonstrating the various fascial planes and their attachments the hardened subject is excellent."

The preserving fluid herein described is readily injected into the bodies by means of a percolator, that is, a reservoir hung four or five

⁴Addison. Quart. Med. Journ., Sheffield, 1897-8, VI, p. 251.

feet above the body with a tube connection to convey the fluid into an artery. The right carotid was always used.

After having injected the preserving fluid, fully twenty-four hours should be let pass before injecting the arteries with starch. It was found that a gelatin injection into the arteries would not stiffen after the use of this injecting fluid.

For storing the embalmed bodies, the writer, toward the end of his period of service in the anatomical department, became interested in the method employed by Shepherd⁵ at McGill University, and tested it sufficiently to demonstrate that it had a probable value above that of cold storage. The method consists in placing the bodies in boxes which can be shut absolutely air-tight, and subjecting them therein to the fumes of alcohol deposited in the bottom of the box. The box should be lead-lined. The writer had the experience that a tightly jointed box made of two-inch plank and not lined, promptly cracked when the fumes of the alcohol were confined within it. Doctor Shepherd, in a recent communication, kindly extended to the writer the courtesy of here quoting from his personal experience with the alcohol method. Doctor Shepherd said: "In these closed tanks we have kept subjects for several years provided they are put in fresh—they neither dry nor mould and make capital subjects because in the dissecting-room they remain fresh."

During dissection the material injected as herein described keeps soft under several layers of damp fabric with all excess of moisture wrung out of the meshes. Too much water dissolves out the chemicals and macerates the tissue. If one desires to preserve the tissues particularly well during a dissection, or over a very long period of time, alcohol is then the best agent with which to moisten the part and to dampen the enveloping fabric. An impervious outer covering aids in preventing too rapid evaporation of the alcohol. To keep the fingers or toes, or other skin surface of one of these bodies exposed to the air from drying, wrap the part in gauze dampened in a solution containing about 10 to 15 per cent of glycerin and about 3 to 5 per cent of carbo'ic acid and then cover the whole with an impervious

⁵Shepherd. Proceedings Association of American Anatomists, May, 1900, p. 23.

covering such as oil cloth. The moisture will be retained for two or three weeks or more. The carbolic prevents maceration of the skin.

A body preserved with the above injection, if properly taken care of, can be dissected during the heat of summer without any offensive odor of decomposition.

Received for publication, December 14, 1908.

BOOK REVIEWS.

STUDIES IN THE MEDICINE OF ANCIENT INDIA. Part I. Osteology, or the Bones of the Human Body. By A. F. Rudolf Hoernle, C.S.E., Ph.D., Hon. M.A. Demy 8vo, pp. xii + 252. 10s. 6d. (\$2.40). At the Clarendon Press, Oxford, 1907.

In this volume, which is evidently the first of a series on the medicine in ancient India, Doctor Hoernle gives a thorough critical analysis of the different systems of osteology as contained in the various manuscripts and versions of Atreya, Sūsruta, Vagbhata and of the Vedas. Though the reviewer is not in a position to judge of the correctness of the author's textual criticisms, it is evident that they are done in a scholarly way. The reader who is looking for general information will, however, often be annoyed by detailed discussions such as that on the use of the word *jatru* on pp. 158-168. These ten pages, for example, are devoted to an explanation and discussion as to how *jatru*, or windpipe, came to be used for clavicle some ten centuries later.

The book is divided into four sections which are devoted to the introduction and chronological summary; to a careful textual criticism of the records of the above named and other writings, to anatomical descriptions, and lastly to the "Apparatus Criticus." Of these sections, the first, parts of the second, and the third, will interest anyone familiar with anatomy or medicine.

According to the author, human dissections were practised in India as early as the sixth century before the Christian era. As evidence the following instructive quotation taken from the fifth chapter of the Anatomical Section (*Sārira Sthāna*) of the Compendium of Sūsruta may be given: "No accurate account of any part of the body, including even the skin, can be rendered without a knowledge of anatomy. Hence anyone who wishes to acquire a thorough knowledge of anatomy must prepare a dead body, and carefully examine all its parts. For it is only by combining both direct ocular obser-

vation and the information of text books that thorough knowledge is obtained. For this purpose one should select a body which is complete in all its parts. It should also be the body of a person who was not excessively old, nor who died of poison or of a protracted disease. Having removed all excrementitious matter from the entrails, the body should be wrapped in rush, or bast or grass, or hemp and placed in a cage. Having firmly secured the latter in a hidden spot, in a river with no strong current, the body should be allowed to decompose. After an interval of seven days the thoroughly decomposed body should be taken out, and very slowly scrubbed with a whisk made of grass-roots or hair or bamboo or bast. At the same time, every part of the body, great or small, external or in internal, beginning with the skin, should be examined with the eye, one after the other, as it becomes disclosed in the course of the process of scrubbing." While the above treatment of the cadaver reminds one of the custom of the old Hebrew anatomists, it is surprising to find such sage advice to the dissector given in so old a Compendium.

Since the training in surgery included puncture of veins, the extraction of teeth, etc., on dead animals, the author's conclusion that dissections of animals were not made seems doubtful and somewhat contradictory of the early history of anatomy elsewhere. That one can rightly speak of a system of osteology at so early a time (sixth century B. C.), and that "no summary of osteological doctrine, such as we find in the writings of Charaka and Sûsruta, appears to exist in any of the known works of the earlier Greek medical schools" is a splendid tribute to the antiquity of learning in ancient India.

Among the many other very interesting and curious facts we find the recognition of red and yellow marrow by Sûsruta and their association with the proper bones; the enumeration of 60 phalanges and 70 ribs out of respect for symmetry; the inclusion of the eyeballs and pinna among the 360 bones of the body, because of their cartilaginous consistency; the conception of the styloid processes and the malleoli as a single composite bone encircling the wrist and ankle respectively; the consideration of the nails as waste products secreted by the bones; the conception of the sockets of the teeth as separate bones, etc., etc.

Students of anatomy and those interested in historical studies owe Doctor Hoernle a debt of gratitude for this interesting volume which was made possible by his painstaking and able studies in a field that is practically unknown to the general reader. The volume is besides a fine piece of book-making.

A. W. Myers.

Received for publication, December 3, 1908.

THE INTEGRATIVE ACTION OF THE NERVOUS SYSTEM. By Charles S. Sherrington, Liverpool. New York, Charles Scribner's Sons, 1906. With 85 figures, xvi + 411 pages. Cloth, \$3.50.

Professor Sherrington's book, which is the series of lectures given at Yale University, has been so many times and so ably reviewed that a systematic review of the book is entirely unnecessary. For example, the significance of the book has been especially well brought out by McDougall in *Brain*, vol. 30, 1907.

On the other hand, although too late to review the book, it may be legitimate to point out certain features which have proved of especial value in the teaching of neurology. The first chapter indicates these features. On the histological side, the theory that in the central nervous system the neurones are independent has been steadily gaining ground through the work of Cajal, Van Gehuchten and others, while on the embryological side conclusive proof has been given by Harrison that the motor nerve to its terminal plates on the skeletal muscle is a process of a single cell. Professor Sherrington gives us evidence on the physiological side. He shows that in function, the reflex arc, involving at least three neurones, has certain characteristics different from nerve conduction and that these differences can be explainable on the hypothesis that there is a plain of separation between the two neurones. These differences are: "(1) Slower speed in reflex arcs; (2) less close correspondence between the moment of cessation of stimulus and the moment of cessation of the end effect; (3) less close correspondence between rhythm of stimulus and rhythm of end effect; (4) less close correspondence between the grading of intensity of the stimulus and the grading of intensity of the end effect;

considerable resistance to passage of a single nerve impulse, but a resistance easily forced by a succession of impulses; (6) irreversibility of direction instead of reversibility as in nerve trunks; (7) fatigability in contrast with the comparative unfatigability of nerve trunks; (8) much greater variability of the threshold value of stimulus than in nerve trunks; (9) refractory period, "bahnung," inhibition, and shock, in degrees unknown for nerve trunks; (10) much greater dependence on blood circulation, oxygen, etc.; (11) much greater susceptibility to various drugs—anaesthetics." The loss of time in reflex arc conduction takes place in the gray matter, and can be explained on the theory that in passing from one neurone to a second the impulse must pass through a zone of protoplasm less highly specialized by conduction than are the neurofibrils. The place of showing of the impulse, where the impulse possibly passes from one neurone to the other, Professor Sherrington calls the synapse.

The second point which we have found of especial interest is that in the medusæ, where anatomists have shown that the nervous system is made of a diffuse nerve net, instead of individual neurones, where there is no specialization of dendrite and axone, the characteristics of reflex arc conduction depending on the synapse are not found. The number of impulses corresponds closely with the stimuli both in number and in rhythm, and there is complete reversibility of conduction, or the impulse is transmitted in all directions from the point of stimulus. Sherrington points out that in nerve conduction and reflex arc conduction there is a refractory phase, but that in the medusa from the observations of Bethe the refractory phase is probably referable to the nerve net, and in the intestine from the work of Magnus the refractory phase is referable to the intrinsic nerve plexus of Auerbach. That is to say in some movements in invertebrates and in some of the movements under control of the sympathetic system in vertebrates the refractory phase is peripheral and belongs to the nerve conduction, while in the more highly specialized movements the refractory phase is central. This seems to suggest to the anatomists that the controversy over the neurone theory may have been due to a reading of results found in one form into another form—and that the simpler relations found in the nerve net of the medusa may be repeated in the sympathetic system of the higher forms.

Sherrington goes on to develop the significance of the more highly specialized or synaptic type of conduction for the skeletal muscles in a series of conceptions that are most helpful in presenting the tracts of the nervous system to students. The first of these is the conception of a common path. He makes plain that the receptive neurone of an arc carries only impulses generated at its own receptive point and hence may be called a *private* path, while the efferent or motor neurone may be excited by a variety of impulses from the various private paths, and hence may be called a public or *common* path. The second of these important conceptions is that of reciprocal inhibition, which is most clearly illustrated in Fig. 37 on page 108. In the medusa there is only the movement possible, the contraction of the bell, but in the antagonistic muscles of the legs of vertebrates, for example, sensory impulses from the skin and the flexor muscles may stimulate a flexion reflex, which must involve an inhibition of the extensors. This he showed experimentally in an animal so prepared that the flexors could not act. Stimulation of the proper skin area gave inhibition of the extensors. The reciprocal inhibition for reflexes on the opposite side as well as on the same side is illustrated in the figure just quoted. The reciprocal inhibition he shows to be a central or synaptic phenomenon. The third general point is that while the motor nerves represent the final common path, the short tracts of the cord and brain stem represent also common paths. These common paths may be used successively by unlike reflexes, but simultaneously by like reflexes. This shows that these common paths, the short tracts in anatomical terms, are a "coordinating mechanism, which prevents confusion by restricting the use of the organ to but one action at a time."

The first part of the eighth chapter gives a valuable review of the experimental work on cerebral localization. The rest of the book is purely physiological with many interesting suggestions, such as the idea that the short tracts are the organs of nervous integration of a segmental series, that the cerebellum is the head ganglion of the proprioceptive system, that is the system of sensory impulses from the organism itself, while the cerebrum is the head ganglion of the distance receptors.

Florence R. Sabin.

Received for publication, December 13, 1908.

PROCEEDINGS OF THE ASSOCIATION OF AMERICAN ANATOMISTS.

TWENTY-FOURTH SESSION.

*In the Anatomical Laboratory, Johns Hopkins University, Baltimore,
Maryland, December 29, 30 and 31, 1908.*

Tuesday, December 29, 9.30 to 12.30 A. M.

The twenty-fourth session was called to order at 9.30 A.M. by the President, Professor James Playfair McMurrich, who appointed the following committees:

Committee on Nominations.—Dr. Robert R. Bensley, Chairman; Dr. Clarence M. Jackson, Dr. Henry McE. Knower.

Auditing Committee.—Dr. Milton J. Greenman, Chairman; Dr. Thomas G. Lee.

ADDRESS OF THE PRESIDENT. CONSERVATISM IN ANATOMY.

SYMPOSIUM ON EXPERIMENTAL EMBRYOLOGY.

1. EDWIN G. CONKLIN, *Princeton University*.—Experiment as applied to the organization and early differentiation of the egg.
2. THOMAS H. MORGAN, *Columbia University*.—The effects produced by centrifuging the egg before and during development.
3. CHARLES R. BARDEEN, *University of Wisconsin*.—Variations in susceptibility of developing organisms to the X-rays at different periods of development.
4. CHARLES R. STOCKARD, *Cornell Medical School, New York City*.—The artificial production of one-eyed monsters and other defects, which occur in nature, by the use of chemicals.
5. WARREN H. LEWIS, *Johns Hopkins University*.—The experimental production of cyclopia in the fish embryos (*Fundulus heteroclitus*).

6. ELIOT R. CLARK, *Johns Hopkins University*.—The tail of the living frog larva as a field for the experimental study of growing and functioning lymphatics.

7. ROSS G. HARRISON, *Yale University*.—The experimental method as applied to the study of the development of the nervous system.

7a. GEORGE L. STREETER, *University of Washington*.—Experimental observations on development of the amphibian ear vesicle. Read by title.

This session closed with the reading of the following general papers:

8. CHARLES S. MINOT, *Harvard Medical School*.—On the blood-destroying function of the mesenchyma.

9. CHARLES S. MINOT.—Is the Teacher-Bryce ovum normal?

10. SIMON H. GAGE AND SUSANNA P. GAGE, *Cornell University*. Coloration of the milk and staining of the fat in suckling rats where Sudan III is fed to the mother.

Tuesday, December 29, 2.00 to 5.00 P.M. Demonstrations as follows:

2.00 to 3.00 P. M.

1. ROBERT R. BENSLEY, *University of Chicago*.—Preparations showing a, Altmann's filaments (chondriosomes) in the pancreas; b, Mankowski's transition between islet and acinus; c, pancreatic islets differentiated in toto by post vitam staining of fresh organs.

2. WARREN H. LEWIS, *Johns Hopkins University*.—Preparations showing a, cyclopia in fish embryos; b, models and drawings showing development of the head in human embryos.

3. J. GORDON WILSON, *University of Chicago*.—Preparations showing a, the nerve supply of the auriculo-ventricular bundle in mammals; b, the nerve supply of the membrana tympani.

4. BENNET M. ALLEN, *University of Wisconsin*.—Preparations showing the origin of sex-cells in *Lepidosteus* and *Amia*. By Charles R. Bardeen.

5. SIMON H. GAGE AND SUSANNA P. GAGE, *Cornell University*. Results of feeding of Sudan III, a, adult rats with fat stained pink; b, week-old suckling rat with colored milk in the stomach and with stained fat; c, four weeks old rat of the same litter with color persisting in the fat; d, hen's egg with red in the yolk; e, pink fat in chicken hatched from such an egg.

3.00 to 4.00 P. M.

6. HENRY McE. KNOWER, *Johns Hopkins University*.—a, Injections of lymphatic system of frog embryos from 6 mm. up; b, injections of the blood vessels of frog embryos from 6 mm. up; c, injecting technique for smaller microscopic vessels; d, specimens showing interventricular muscle bands of the human heart.

7. ROBERT RETZER, *Johns Hopkins University*.—a, A quick method of demonstrating nerves, with especial reference to the extrinsic nerve supply of the heart; b, the conductive system in dissections of adult mammalian hearts, and in sections showing its development in the pig; c, papillary muscles and moderator band; d, injected coronary arteries in adults and embryos.

8. HERBERT M. EVANS, *Johns Hopkins University*.—a, Injected bird and mammalian embryos to illustrate the mode of development of the chief vessels; b, injected duck and chick embryos to illustrate paper on "The earliest blood-vessels in the limb bud of birds and their relation to the primary subclavian;" c, preparations showing the blood vessels of the human small intestine.

9. ELIOT R. CLARK, *Johns Hopkins University*.—a, Drawings of successive stages in blood vessels and lymphatics in the tail of the same frog larva with apparatus used in making the observations; b, specimens of injected pig embryos to show the development of the blood supply of the femur.

10. FLORENCE R. SABIN, *Johns Hopkins University*.—a, Lymphatic sacs, the transformation of sacs into lymph nodes and the jugular valves in the human embryos; b, the mesenteric sac in pig embryos.

11. JOHN B. JOHNSTON, *University of Minnesota*.—a, Sections of foetal human brains to show connection of the mesencephalic root

of the trigeminus with the sensory root; b, sections of pig embryos to show the velum transversum on paraphysis; c, sections of amphibian embryos to show the history of the optic chiasma and optic recess; d, sections of amphibian embryos to show the formation of the mouth and the origin of taste-buds in the entoderm.

4.00 to 5.00 P. M.

12. WESLEY M. BALDWIN, *Cornell University Medical College, Ithaca*.—a, Eleven specimens of human duodenum with duodenal diverticula; b, a human duodenum completely encompassed by pancreatic tissue. By Abram T. Kerr.

13. JOSEPH H. HATHAWAY, *Cornell University Medical School, Ithaca*.—Photographs of cases showing supernumerary nipples in the male. By Abram T. Kerr.

14. J. P. SCHAEFFER, *Cornell University Medical School, Ithaca*. Models of the sinus maxillaris in the embryo and specimens of the sinus maxillaris in the adult. By Abram T. Kerr.

15. RICHARD H. WHITEHEAD, *University of Virginia*.—A case of cyclopia.

16. MR. LISSER, *Johns Hopkins Medical School*.—Models to show the development of the human larynx.

17. EDWIN C. CONKLIN, *Princeton University*.—A new form of automatic microtome.

18. MILTON J. GREENMAN, *Wistar Institute of Anatomy*.—A new gas regulator.

19. ALDRED S. WARTHIN, *University of Michigan*.—Hemolymph nodes with especial reference to certain disputed points. By G. Carl Huber.

8.00 P. M.—Smoker in conjunction with the American Physiological Society and the American Society of Biological Chemists, Johns Hopkins Club, Corner of Monument and Howard Streets.

8.00 P. M.—Reception at the College Club, 821 North Charles Street, to the women who are members of the Association and to the wives of members.

Wednesday, December 30, 9.15 A. M. to 12.30 P. M. Session for the reading of papers, the President, James Playfair McMurrich, and the Second Vice-President, Dr. Florence R. Sabin, presiding.

11. HARVEY E. JORDAN, *University of Virginia*.—A study of a 5 mm. normal human embryo.

12. HARVEY E. JORDAN.—A study of pathological cat embryos.

13. WARREN H. LEWIS, *Johns Hopkins Medical School*.—The development of the muscles of the head in man. Read by title.

14. ROBERT RETZER, *Johns Hopkins University*.—Remarks on the dyes used in histological laboratories.

15. HENRY McE. KNOWER, *Johns Hopkins University*.—The development of the blood vessels and lymphatics of the muscle segments in frog larvæ with a comparison of the cerebral and segmental blood vessels in frog, chick and mammalian embryos.

16. HERBERT M. EVANS, *Johns Hopkins Medical School*.—On the development of the aorta, cardinal veins, umbilical veins and other vessels of the vertebrate embryo from capillaries.

17. ROBERT R. BENSLEY, *University of Chicago*.—Studies on the pancreas:—a, Altmann's filaments (chondriosomes) in the pancreas and in other organs; b, Mankowski's transition between islet and acinus; c, a method of differentiation of the islets in toto by post vitam staining of fresh organs.

18. BENNET M. ALLEN, *University of Wisconsin*.—The origin of the sex-cells in *Lepidosteus* and *Amia*. Presented by Charles R. Bardeen.

19. CLARENCE M. JACKSON, *University of Missouri*.—Notes on developmental topography.

20. LEO LOEB, *University of Pennsylvania*.—a, Experimental production of decidua in the rabbit; b, observations on the growth and retrogression of the corpus luteum in the Guinea pig. The latter read by title.

21. J. M. STOTSENBURG, *Wistar Institute of Anatomy*.—On the effect of castration on the growth of the albino rat (*Mus norvegicus* var. *albus*). Introduced by H. H. Donaldson. With lantern.

22. S. HATAI, *Wistar Institute of Anatomy*.—A comparison of the albino with the grey rats in respect to the weight of the brain and spinal cord. With lantern.

23. HENRY H. DONALDSON, *Wistar Institute of Anatomy*.—On the relation of the body length to the body weight of the central nervous system in the albino rat (*Mus norvegicus* var. *albus*). With lantern.

24. HEIKOBUS J. H. HOEVE, *Drake University*.—Lantern demonstration of brain dissections made by a new method.

Wednesday, December 30, 2 P. M. Business meeting.

On motion of Dr. Clarence M. Jackson, the minutes of the Secretary, as printed in the *Anatomical Record* (The American Journal of Anatomy, Vol. VII, No. 4), pages 201 to 208, were approved.

The Treasurer made the following report for the year 1908:

Total receipts for the year 1908.....	\$1,136.40	
Balance on hand December 29, 1907.....	108.52	
		<hr/> \$1,244.92

Expenditures for 1908:

Expenses of Secretary, Chicago meeting.....	22.25	
Smoker, Chicago meeting	40.00	
Stamps	15.00	
Printing	25.00	
Typewriting	5.50	
To the Publication Department of The Wistar Institute for 214 subscriptions to Ameri- can Journal of Anatomy	963.00	
		<hr/> \$1,072.75

Balance on hand December 24, 1908, deposited in Farmers' and Mechanics' Bank, Ann Arbor, Mich.	\$172.17
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Dr. Thomas G. Lee reported for the Auditing Committee: "We have examined the Treasurer's accounts for 1908 and found them correct."

On motion of Dr. Franklin P. Mall, the reports of the Treasurer and Auditing Committee were accepted and adopted.

The Secretary reported for the Executive Committee that Professor Charles S. Minot had been appointed a representative from the Association to confer with the Executive Committee of the American Society of Naturalists and representatives of other affiliated scientific societies relative to the further policy of the American Society of Naturalists and its relation to other affiliated scientific societies.

Dr. Robert R. Bensley, as chairman of the committee on nomination, placed before the association the name of Dr. Henry H. Donaldson as member of the Executive Committee for term expiring 1913.

On motion the secretary was instructed to cast a ballot for the election of Dr. Henry H. Donaldson as member of the Executive Committee for term expiring 1913. Carried.

The committee on revision of the Constitution of the Association of American Anatomists, consisting of Dr. G. Carl Huber, chairman, Dr. Henry H. Donaldson, and Dr. Robert R. Bensley, made the following report which was placed before the association and will be acted upon at its next annual meeting.

CONSTITUTION.

ARTICLE I.

Section 1. The name of the Society shall be the "American Association of Anatomists."

Section 2. The purpose of the Association shall be the advancement of anatomical science.

ARTICLE II.

The officers of the Association shall consist of a President, a Vice-President, and a Secretary, who shall also act as Treasurer. The President and the Vice-President shall be elected for two years, the Secretary for four years. In case of absence of the President and Vice-President the senior member of the Executive Committee shall preside.

ARTICLE III.

The management of the affairs of the Association shall be delegated to an Executive Committee, consisting of eleven members, including

the officers. Two members of the Executive Committee shall be elected annually, and so far as possible election of members of the Executive Committee shall be in proportion to the geographical distribution of members. Five shall constitute a quorum of the Executive Committee.

ARTICLE IV.

The Association shall meet at least annually, the time and place to be determined by the Executive Committee. The annual meeting for the election of officers shall be the meeting of convocation week, or in case this is not held, the first meeting after the new year.

ARTICLE V.

Section 1. Candidates for membership must be persons engaged in the investigation of anatomical or cognate sciences, and shall be proposed in writing to the Executive Committee by two members, who shall accompany the recommendations by a list of the candidates' publications, together with references. Their election by the Executive Committee shall be ratified by the Association in open meeting.

Section 2. Honorary members may be elected from those not Americans who have distinguished themselves in anatomical research. Nominations by the Executive Committee must be unanimous and their proposal with reasons for recommendations shall be presented to the Association at an annual meeting, a three-fourths vote of members being necessary for an election.

ARTICLE VI.

The annual dues shall be five dollars. A member in arrears for dues for two years shall be dropped by the Secretary at the next meeting of the Association, but may be reinstated, at the discretion of the Executive Committee on payment of arrears.

ARTICLE VII.

Section 1. Twenty members shall constitute a quorum for the transaction of business.

Section 2. Any change in the constitution of the Association must be presented in writing at one annual meeting in order to

receive consideration and be acted upon at the next annual meeting; due notice of the proposed change to be sent to each member at least one month in advance of the meeting at which such action is to be taken.

Section 3. The ruling of the Chairman shall be in accordance with "Roberts' Rules of Order."

During the informal consideration given the report of this committee the suggestion was made that Section 1 of Article I be further changed to read "The name of the society shall be the Association of Anatomists."

The following were recommended by the Executive Committee for election to membership in the association:

JOS. C. BLOODGOOD, M.D., Surgeon, Johns Hopkins University.

RALPH V. CHAMBERLIN, B.S., PH.D., Professor of Zoölogy, University of Utah, Salt Lake City.

ELBERT CLARK, S.B., Assistant in Anatomy, University of Chicago.

THOMAS S. CULLEN, M.B., Gynecologist, Johns Hopkins University.

ULRICH DAHLGREN, M.S., Assistant Professor of Biology, Princeton University.

DAVID M. DAVIS, B.S., Johns Hopkins Medical School, Baltimore.

A. FRANCIS DIXON, M.B., Sc.D., Professor of Anatomy, Trinity College, Dublin, Ireland.

JAMES A. GIBSON, M.D., Professor of Anatomy, University of Buffalo.

WILLIAM A. HILTON, B.S., PH.D., Instructor in Histology and Embryology, Cornell University.

HEIKOBUS J. H. HOEVE, M. D., Professor of Anatomy, Drake University.

HANS LISSER, A.B., Johns Hopkins Medical School, Baltimore.

GUSTAVE MARM, M.D., B.Sc., Professor of Physiology, Tulane University, New Orleans.

ADAM M. MILLER, A.M., Instructor in Histology and Embryology, College of Physicians and Surgeons, New York City.

STEPHEN W. RANSON, M.D., Ph.D., Associate in Anatomy, Northwestern University Medical School, Chicago, Ill.

JACOB PARSONS SCHAEFFER, B.E., M.E., M.D., Instructor in Medical Anatomy, Cornell University Medical College, Ithaca, N. Y.

HELEN W. SMITH, A.B., Johns Hopkins Medical School, Baltimore.

EDWIN CHAPIN STARKS, Assistant Professor of Zoölogy, Leland Stanford University.

On motion, the secretary was instructed to cast a ballot for election to membership in the Association of American Anatomists of applicants recommended by the Executive Committee. Carried.

After the business meeting the members attended the following demonstrations:

20. CHARLES R. ESSICK, *Johns Hopkins Medical School*.—Preparations showing the development of the corpus ponto-bulbare.

21. MISS SMITH, *Johns Hopkins Medical School*.—Specimens showing development of the veins in the body wall of the pig.

22. LEO LOEB, *University of Pennsylvania*.—Preparations showing a, experimental production of the decidua in the rabbit; b, the growth and retrogression of the corpus luteum in the Guinea pig.

23. RALPH H. MAJOR, *Johns Hopkins Medical School*.—Preparations and drawings showing the vascular supply of the thyroid gland.

24. MAX BROEDEL, *Johns Hopkins Medical School*.—a, Exhibition of work of students made in class in Anatomical drawing; b, exhibition of drawings and some of the methods of their reproduction.

25. JOHN L. BREMER, *Harvard Medical School*.—Preparations showing the aberrant roots and branches of the abducent and hypoglossal nerves.

26. ALVIN DAVIDSON, *Lafayette College*.—Bone preparations prepared after a new method.

27. MONTROSE I. BURROWS, *Johns Hopkins Medical School*.—Preparations showing the vascular supply of the adult medulla oblongata.

4.00 to 5.00 P. M.

28. N. WILLIAM INGALLS, *Medical College, Western Reserve University*.—Detail models of various parts of a 4.9 mm. human embryo.

29. WALTER E. DANDY, *Johns Hopkins Medical School*.—Wax-plate model of a human embryo of 2 mm. length.

30. HARVEY E. JORDAN, *University of Virginia*.—Sections of a 5 mm. normal human embryo.

31. WILLIAM H. F. ADDISON, *Medical Department, University of Pennsylvania*.—Preparations showing lamellar corpuscles between the brachial artery and vein in man.

32. JAMES MURPHY, *Johns Hopkins Medical School*.—Types of the sulcus lunatus in negro and white brains.

33. HEIKOBUS J. H. HOENE, *Drake University*.—Preparations of human brain prepared after a new method.

DEMONSTRATION OF JOURNAL METHODS IN THE ROOMS SET APART FOR JOURNALS.

Thursday, December 31, 9.30 A. M., to 1.15 P. M. Session for the reading of papers, President, James Playfair McMurrich, and Professor Simon H. Gage, presiding.

25. CHARLES R. ESSICK, *Johns Hopkins Medical School*.—The embryology of the corpus ponto-bulbare and its relation to the development of the pons.

26. ELIZABETH H. DUNN, *University of Chicago*.—On the course of the cortical tangential fibers developing after the ablation of the encephalic cortical substance. Read by title.

27. RALPH E. SHELDON, *University of Chicago*, and CHARLES BROOKOVER, *Buchtel College*.—The nervus terminalis in teleosta. Read by title.

28. C. JUDSON HERRICK, *University of Chicago*.—The nervus terminalis (nerve of Pinkus) in the frog. Read by title.

29. JOHN B. JOHNSTON, *University of Minnesota*.—a, The morphology and subdivisions of the forebrain vesicle in vertebrates; b,

the limits of the ectoderm and entoderm in the mouth and the origin of the Taste-buds.

30. J. GORDON WILSON, *University of Chicago*.—The nerve supply of the auriculo-ventricular bundle in mammals.

31. RICHARD H. WHITEHEAD, *University of Virginia*.—The interstitial cells in the testis of an hermaphrodite horse.

32. G. P. SCHAEFFER, *Cornell University Medical College, Ithaca*.—The sinus maxillaris in the embryo, child and adult and its relation to the sinus frontalis.

33. JOSEPH H. HATHAWAY, *Cornell University Medical School, Ithaca*.—Occurrence of supernumerary nipples in the male, based on an examination of college students.

34. WESLEY M. BALDWIN, *Cornell University Medical College, Ithaca*.—a, A report on a series of duodenal diverticula in man; b, Report on a specimen of duodenum in man completely encompassed by pancreatic tissue.

35. FREDERICK T. LEWIS, *Harvard Medical School*.—a, Keibel's note on intestinal diverticula; b, An anomaly of the subclavian vein and its possible embryological interpretation.

36. MAX BROEDEL, *Johns Hopkins University*.—Rotation of the human kidney in its development and its influence on a, the form of the kidney; b, the topography of the pelvis and calices; c, the type of its vascularization.

37. ARTHUR W. MEYERS, *Northwestern University Medical School*.—a, Further observations on subcutaneous and subpannicular hemolymph nodes; b, the occurrence of intrathoracic parathyroid glands.

38. ALVIN DAVIDSON, *Lafayette College*.—A new method of preparing bone.

39. MR. CLARK, *University of Chicago*.—The glands of the frontal sinuses. Introduced by J. Gordon Wilson.

40. J. P. SCHAEFFER, *Cornell University Medical College, Ithaca*.—A statistical study of the palmaris longus muscle.

41. JOSEPH H. HATHAWAY, *Cornell University Medical College, Ithaca*.—Variations in the origin of the brachialis muscle.

42. HARRIS H. WILDER, *Smith College*.—The work in human Anatomy at the University of Athens. Read by title.

43. ROBERT RETZER, *Johns Hopkins University*.—a, Notes on the study of the development of the coronary arteries; b, the development of the moderator band and its relation to the papillary muscles; c, the cytological structure of the heart musculature in the various parts of the heart. Read by title.

44. B. F. KINGSBURY, *Cornell University*.—a, The morphology of the sound transmitting apparatus in amphibia; b, Report of a case of hermaphroditism in *Sus scrofa*. Read by title.

45. R. V. CHAMBERLIN, *University of Utah*.—On the mode of disappearance of villi from the colon of mammals. Read by title.

At the close of the session, on motion of Dr. G. Carl Huber, seconded by Dr. Charles S. Minot, the association expressed its thanks and appreciation to the members of the anatomical staff of Johns Hopkins University for the very successful arrangements made for the meeting and for the many courtesies shown to the members of the association.

On motion the association adjourned.

Abstracts of papers presented and announced will appear in forthcoming numbers of THE ANATOMICAL RECORD.

G. CARL HUBER,

Secretary and Treasurer.

Received for publication, January 13, 1909.

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No. 2

THE COURSE OF THE BLOOD THROUGH THE HEART OF THE FETAL MAMMAL, WITH A NOTE ON THE REPTILIAN AND AMPHIBIAN CIRCULATIONS.

BY

AUGUSTUS GROTE POHLMAN,
Indiana University.

The problem of the course of the blood through the heart of the fetal mammal has been taken up because there are three distinct theories regarding the fate of the blood entering the heart through the superior and inferior caval veins. Each of these theories is based upon anatomical findings—a correlation of function to structure, and while injection experiments have been carried out which seem to substantiate each theory, experimental evidence derived from a study of the fetal circulation in the living embryo is entirely lacking. It is our purpose, therefore, to review the important literature; to state the position of the various theories together with their modifications; to analyze critically the evidence produced by the observers; to present the results of personal findings in the living mammalian embryo; and to offer a general summary of the physical, anatomical, and pathological evidence in favor of the one as opposed to all other theories. Finally to give a preliminary account of our observations on the circulation of the reptile and amphibian.

The literature up to the time of Harvey (1628) is drawn from Dalton's excellent work. Extremely comprehensive reviews are to be found in Knabbe's dissertation in Latin, and also in Kilian's article in German. With the exception of the first six references, where direct control is offered by comparison with the original text, and of Wolff's treatise, the articles have been read personally. The reader is referred to literature reviews mentioned for more exhaustive study.

The first definite information on the structure of the fetal heart is found in Galen's work: "In this matter, we have reason to admire the provisions of nature. For so long as the lung has only to be nourished and grow, it is supplied simply with blood; but, when it is ready to take on an active motion, its tissue becomes lighter and capable of expansion and compression by the movements of the chest. On that account the vena cava (right auricle), in the fœtus, communicates by an opening with the arteria venalis (left auricle). As this latter vessel thus performs for the lung the office of a vein (that is, supplies it with blood for its nourishment), its companion (the pulmonary artery) must need at this time serve the purpose of an artery, and it is consequently made to communicate with the aorta. As these two vessels (pulmonary artery and aorta) are situated a little distance apart, their communication is effected by means of a third smaller one (ductus arteriosus), which forms a junction with each. In the case of the other two (auricles), which lie in contact with each other, there is a kind of orifice or fenestra (foramen ovale) common to both. At this orifice there is attached a membrane, like a lid or cover, opening toward the pulmonary vessel (left auricle), so that it will yield to the influx of blood from the vena cava (right auricle), but will prevent its regurgitation into that vessel."

Galen furthermore mentions the fate of the foramen ovale and the ductus arteriosus after birth. It must be remembered that at this time (third century) practically all of the work on the heart had been done hundreds of years before by Aristotle, Herophilus and Erasistratus, and despite the investigations of the latter two men on the character of the veins and arteries and the valves in the heart, the doctrine of circulation was shrouded in mystery. Galen assumed that the blood passed from the right into the left ventricle through the ventricular septum, and this may in part account for the curious notion that the ductus arteriosus transmitted blood from the aorta into the pulmonary artery—the passage is ambiguous and this is one interpretation of it. His description, however, of the foramen ovale, its valve and the method of its obliteration, together with the atrophic changes in the ductus arteriosus, are quite accurate.

Some thirteen centuries later Vesalius questioned the teachings of Galen regarding the passage of blood through the ventricular septum. "And accordingly, notwithstanding what I have said about the pits in this situation, and at the same time not forgetting the absorption by the portal vein from the stomach and intestines, I still do not see how even the smallest quantity of blood can be transfused, through the substance of the septum, from the right ventricle to the left." While this questioning the infallibility of Galen's work was little more than rank heresy at the time, Vesalius paved the way for others, and doubt was again raised in Servetus' discovery of the pulmonary circulation in 1553.¹ Servetus says, "This communication, however, does not take place through the median wall of the heart, as commonly believed; but by a grand device the refined blood is driven from the right ventricle of the heart, in a long course through the lungs. By the lungs it is prepared, assuming a bright color, and from the vena arteriosa is transferred into the arteria venosa" (pulmonary vein). Servetus also recognized the foramen ovale, and but for his unitarian views, which resulted in his untimely death at the stake, might have contributed more than a mere description of the pulmonary circulation.

The contemporaries of Vesalius and Servetus, Columbus and Cæsalpinus are also to be mentioned in this connection. We fail to see, however, wherein Columbus bettered the description given by Servetus, and Cæsalpinus did not add materially to what was already known on the subject. It must not be thought that the newer teachings were eagerly accepted, for Fallopius held to the Galenic views to the time of his death (1563). In 1565 Botallus reported the persistence of the foramen ovale and re-described the ductus arteriosus. We agree with many other writers that the use of Botallus' name in connection with these structures is questionable since Galen first mentioned them.

The gradual relief from religious persecution and the works of Vesalius and others stimulated investigation. Comparative anatomy,

¹We do not care to enter into a discussion of who actually did discover the pulmonary circulation and favor Servetus for the reason that his work appeared six years before that of Columbus.

particularly the investigations of Harvey, threw new light on the question. In Harvey's classical work (1628) we note the first scientific description of the course of the blood through the fetal heart. Unfortunately, the terminology is rather vague and the translation leaves much to be desired. For example, Harvey uses the term 'vena cava' as Galen used it—to denote the right auricle, while the left auricle is termed *arteria venosa* or pulmonary vein; the translator supplied plurals to these structures 'venæ cavæ' and 'pulmonary veins' at discretion, and the meaning is far from being the same. We present a corrected excerpt from Harvey's work, which reads as follows: "The first contact and union of the vena cava (right auricle) with the pulmonary vein (left auricle) which occurs before the vena cava opens into the right ventricle, or gives off the coronary sinus, a little above its escape from the liver, exhibits a lateral anastomosis that is a wide open passage-way from the cava (right auricle) into the vessel already mentioned (left auricle); in such a manner, that (as if by a single vessel) the blood can flow very freely and copiously through that opening from the vena cava into the left auricle and through the left auricle all the way into the left ventricle."

Note the similarity of this passage to the description given by Galen. We must give Harvey credit that he knew of the two caval veins and of the multiple pulmonary veins, otherwise the passage would mean nothing. It is generally accepted that the interpretation is as follows—the blood contained in the right auricle passes through the foramen ovale into the left auricle. He continues: "Further, in this foramen ovale, from the part which regards the pulmonary vein, there is a thin tough membrane, larger than the opening, extended like an operculum or cover; this membrane in the adult blocking up the foramen, and adhering on all sides, finally closes it up, and almost obliterates every trace of it. In the *fœtus*, however, the membrane is so contrived that falling loosely upon itself, it permits a ready access to the lungs and the heart, yielding a passage to the blood which is streaming from the cava (right auricle), and hindering the tide at the same time from flowing back into that vein. All things, in short, permit us to believe that in the

embryo the blood must constantly pass by this foramen from the vena cava into the pulmonary vein, and from thence into the left auricle of the heart; and having once entered there, it can never regurgitate."

It was many years before Harvey's doctrine of the circulation in the adult was generally accepted, while his views concerning the course of the blood through the fetal heart were greatly obscured through the work of Méry, who claimed to demonstrate the passage of blood from left to right. Méry says, "*L'hypothèse du passage du sang de l'oreillette gauche par le trou ovale dans le ventricule droit du cœur du fœtus humain que j'y propose comme une simple conjecture, n'y appuyée que sur le seul rapport que j'ay trouvé entre le trou ovale et le canal de communication du cœur de la Tortue, et les mêmes conduits du fœtus.*"

This position was championed successfully by Méry throughout his life and despite the objections raised by Duverney and others, it was approved by Winslow, Littre and practically the entire French Academy. Winslow speaks of the anomaly reported by Vieussens where no foramen ovale was present (heart incompletely described—probably ventricular defect), and Steno's case of defect in the ductus (probably incomplete separation of the ventral aortic stem).

Some years after Méry's death, the injection experiments of Trew and Roederer proved the scheme a faulty one and in the work of von Haller we find no mention of it whatever. Here again are found vague descriptions; the wording is suggestive of Galen and Harvey, while the context appears to be a forerunner of the Sabatier theory. "But yet the septum betwixt the right and left auricle, conjoining them together, is perforated by a broad oval foramen, through which the blood coming from the abdomen, and a little directed or repelled by the valvular sides of the auricle, flows in a full stream into the pulmonary sinus." In 1773 Sénac repeated Méry's injection experiments and found that blood passed from the right into the left auricle but not the reverse.

About this time Wolff found that the relation of the opening of the inferior cava to the foramen ovale was somewhat different than hitherto described. He placed the orifice of the inferior cava dorsally at the border between the two auricles and considered the auricular

septum to be defective in this situation (foramen ovale). The orifice of the cava inferior was, therefore, split on the limbus Vieussens in such a manner that the left part of the opening transmitted blood directly into the left auricle through the foramen ovale, while the right part of the opening connected with the right auricle. The foramen ovale, in other words, did not afford a communication between the two auricles. This theory differs from the following one in that it was based on anatomical findings rather than inferred physiological necessity.

Some years later Sabatier presented his famous theory on the course of the blood through the fetal part. In his article, he deals with the formation of the inferior cava, devotes a few lines to the passage of blood through the liver, and says of the blood entering the heart through the inferior cava, "Le trou ovale le transmet a l'oreillette gauche." Practically v. Haller's statement. The theory was accepted by Bichat and incorporated in his text book on descriptive anatomy: "All the blood that the trunk of the inferior cava receives, . . . , instead of stopping in the right auricle, as in the adult, passes entire into the left through the foramen ovale, the superior edge of which is so arranged that nothing can mix with the blood of the superior cava; so that it is really with the left auricle that the inferior cava is continued." As we read the literature, it appears that this was really the scheme proposed by von Haller a few years before, but it was probably suggested independently by Sabatier. This theory, the prevalent one to-day, was confirmed by Horner, Murray, and Reid.

Wolff's anatomical findings were substantiated by Kilian: "Die Vena cava inferior öffnet sich nicht allein in den rechten Vorhof, sondern sie ergiesst ihr Blut durch zwei vollkommen isolierte Mündungen durch eine rechte und eine linke, sowohl in das rechte, als wie in das linke Atrium." Kilian, however, went still farther and his monumental work probably came into disrepute because of the curious view he held regarding the distribution of the blood from the right and left ventricles. "Es giebt im Fœtus noch keine Arteria pulmonalis, sondern die fälschlich mit diesem Namen belegte Arterie, sammt dem sogenannten Ductus arteriosus Botalli, sind

ein und dasselbe fortlaufende Gebilde und der Ursprung eines sich in die untere Körperhälfte fortsetzenden Gefäßes, welches den Namen Aorta abdominalis zu tragen verdient, im Gegensatze der Aorta cerebralis, welche aus dem linken Ventrikel entspringt." Kilian believed that all of the blood of the left ventricle went to the head and upper extremities, while the blood from the right side was distributed to the lungs and Aorta descendens. An Aorta cerebralis, therefore, in contradistinction to an Aorta abdominalis.

Meckel's case occlusion of the descending aorta at the fourth thoracic vertebra seemed to conform with this scheme, but a careful examination of the drawing shows the constricted area to be well marked above, as well as below, the remains of the ductus. Even granting Kilian's scheme, the case could not represent a persistence of fetal conditions.

Injection experiments were carried on by Reid (1835) in three specimens. He injected a red mass into the cava inferior and a yellow mass into the cava superior, equal quantities under equal pressure; and found in one, that some of the red passed into the right auricle, none into the ventricle, while it filled the left ventricle. In this case a mistake was made of injecting the superior cava the wrong way. In the second attempt, the two masses mixed in the right auricle, with the comment that the injection was not well managed. The third case showed no mixing of the two masses; all the red went to the head, while all the yellow into the Aorta descendens. In his second article, commenting on the first, Reid mentions that he agrees with Sabatier but also states that Magendie's Physiology considers the scheme impossible, while Bostock's Physiology alludes to it as fanciful.

The chief objections to the von Haller-Sabatier theory were taken by Williams and by Peaslee. Williams's article, lamentably hidden, is worthy of no little consideration, because it represents the first critical analysis of the scheme. "From a careful examination of the anatomical character and dependence of the Eustachian valve, notwithstanding the opposing experiments of Dr. John Reid, I have recently convinced myself that it is mechanically inefficient as a means of preserving the individuality of the two caval currents

as they traverse the chamber of the right auricle; at the period of its diastole, when the auricle has attained a moderate limit of distension, it may be readily demonstrated, that the two streams must freely intermingle. It is not true, therefore, that the difference in quality is so considerable as that generally taught by the anatomists between the blood distributed to the anterior segment and that circulating the posterior segment of the body of the fœtus." Peaslee, who by the way believed in a marked aspirating action of the auricles, arrived at a similar conclusion. He considered "The foramen ovale, a temporary arrangement to allow the rapid conversion of the reptilian to the mammalian heart," the "mixture of blood in the right auricle," and that "no artery in the fœtus contains arterial blood." The statement regarding the conversion of reptilian to mammalian heart is probably a slip in English—what he undoubtedly meant was a change from the type of reptilian circulation to that of the mammal. With no article published in its favor since 1835, the von Haller-Sabatier theory came into disrepute in the literature even if it still occupies its original prominence in the text books on anatomy, physiology, embryology and obstetrics, both human and comparative.

With Rüdinger's finding that the orifice of the inferior cava was divided on the limbus Vieussens as described by Wolff, Kilian and others, interest seemed to be reawakened in the course of the blood through the fetal heart. Preyer, although a champion for the Wolff theory, still inclined toward the idea that the head of the embryo received a better arterial supply and this he gained as follows: The circulation through the lungs he granted was free, and inasmuch as the fetal lung occasioned little waste, the return through the pulmonary veins would be of better quality than the return through the superior cava; now inasmuch as the blood of the inferior cava was passed in equal amounts to both ventricles, the left ventricle would contain a more arterial blood. The idea in a way offers a compromise between the Wolff and von Haller-Sabatier theories and is incorporated in the elaborate scheme of the fetal circulation in Preyer's book.

Ziegenspeck, working under Preyer, waived the question as to

the quality of blood and presented a unique scheme for the placental circulation. The heart was diagrammed as two hearts, in order to render evident the Wolff idea that the foramen ovale did not afford communication between the two auricles, and this in turn necessitated picturing the vena cava inferior as a forked vein. The scheme proved confusing and in his last article he has redrawn his figure which we present later.

In review, we find the following theories arranged in chronological order:

I. The theory of Galen-Harvey (300[?] and 1628). Foramen ovale affords communication between the two auricles. Passage of mixed blood from right to left.

II. The theory of Méry (1692). Passage of blood from the left auricle to the right ventricle through the foramen ovale.

III. The theory of Wolff (1775). Foramen ovale does not afford communication between the two auricles but connects with the left opening of the vena cava inferior. Right opening of that vein leads into the right auricle.

IV. The theory of von Haller-Sabatier (1779-91). Blood of the inferior cava passes over to left auricle through foramen ovale. Foramen ovale does not connect the two auricles.

V. The theory of Kilian (1826). Same as that of Wolff with this modification—division of vessels leaving the heart into Aorta cerebialis and Aorta abdominalis. Descending aortic arch conveys no blood during fetal life.

VI. The theory of Ziegenspeck (1881 and 1905). Same as that of Wolff with modification; that return to heart through superior cava equals return through pulmonary veins; that Pars communicans aortæ transmits the same amount of blood as ductus and that each carries one half of the contents of the left and the right ventricles respectively. "Gesetz der Halbierung des Blutes."

Méry's theory was refuted in the eighteenth century. Kilian's theory has not met with approval since 1835 and neither has the von Haller-Sabatier scheme. The latter one, however, demands some attention. We, therefore, consider it first, next the Wolff and Ziegenspeck contentions, and finally the theory of Galen-Harvey.

THE THEORY OF VON HALLER-SABATIERE.

This theory may be interpreted in one of two ways: either the orifice of the inferior cava is placed in close relation to the foramen ovale and that all or practically all of its blood passes to the left; or, interpreted from the usual diagrams, the streams from the two cavæ cross in the chamber of the right auricle without mixing. The only difference between the former interpretation and the Wolff theory is one of degree and we, therefore, consider it later. We present our criticism to the latter reading taken from a preliminary article. "A critical examination of this theory shows it to be physically impossible, morphologically inaccurate, and developmentally unnecessary." We believe it is simple to show that it is physically impossible to preserve the identity of two currents when they cross within a distending chamber. Born has already pointed out the morphological inaccuracy of the scheme in that the condition is not to be found in the sauropsidian embryo. The scheme is developmentally unnecessary. It attempts to account for the more rapid growth of the head because that segment then obtains the better quality of blood. The head end of all vertebrates develops more rapidly than the tail end whether this alleged better arterial supply is present or not.

It is our opinion that the von Haller-Sabatier scheme of the fetal circulation should be eliminated from the text books except as a matter of historical interest, and we also believe that the investigators favoring the Wolff school will concur in this statement. This represents the neutral ground, and from here on we differ.

THE THEORY OF WOLFF, INCLUDING ZIEGENSPECK'S MODIFICATION.

This theory is based on the anatomical findings that the orifice of the inferior cava is placed dorsally on the auricular septum which is deficient at this point. The free edge of the septum constitutes the limbus Vieussens, and the current in the inferior cava is directed against it in such a manner that the blood is split into two streams; the left part of the current passes to the left of the limbus directly into the foramen ovale, while the right part passes to the right of

the limbus directly into the right auricle. The foramen ovale does not afford communication between the two auricles and inasmuch as the more arterial blood in the inferior cava is distributed to both ventricles, a mixing of bloods, arterial and venous, occurs in both ventricles. Ziegenspeck's work is the most scientific and recent and we, therefore, direct our attention to his article on the subject.

Ziegenspeck criticises both the von Haller-Sabatier and Galen-Harvey theories. We agree that the former is incorrect, but, inasmuch as we favor the latter, we present his views on the question.

Ziegenspeck claims that the Galen-Harvey theory is refuted; first, by the anatomical findings of Wolff which he substantiates, and second, "Wer kann bei Betrachtung der Abbildungen, . . . , es für wahrscheinlich oder möglich halten, dass während der Diastole beider Vorhöfe, *währendem doch beide aspirieren*, ein Blutstrom sich durch die rechte Mündung nach rechts, dann wieder durch dieselbe Mündung nach links ergiessen? Ist es nicht vielmehr ohne weiteres klar, dass sich jeder Vorhof aus der Vena cava inferior direct so viel Blut aspiriert, als zu seiner Füllung noch nötig ist?" We can answer the question quite frankly—it is not clear.

While we are tempted to agree with Ziegenspeck that the illustrations he presents seem to support the argument, and while these relations appear to hold in pig (the animal used in our experiments), we would hesitate before accepting these conditions to obtain necessarily in the living animal. Practically Born's criticism. Again we note that particular emphasis is laid upon an aspirating action of the auricles, a point also mentioned by Peaslee in his claim for a mixing of the blood. It must be remembered that the aspirating action of the auricles is by no means a certainty and that even if it be present, it is probably feeble and transient.

The physical data offered by Ziegenspeck are based on the following premise: if both ventricles expel the same amount of blood under the same pressure, then the vessels transmitting the blood must be of like caliber. Upon this assumption, therefore, if the ductus and Pars communicans aortæ (segment of aorta between left subclavian artery and ductus) are of like caliber, they carry equal quantities of blood. He tabulates 33 measurements; in 28

the two are of equal caliber; in 2, the ductus is larger, and in 3, the Pars communicans aortæ is larger. Allowing for variation, he deduces that the two structures transmit equal quantities of blood.

According to the laws of hydrodynamics, we should have a direct control as to the scientific value of these measurements, for we are able to compute the caliber of the Aorta descendens and compare it with the measured value. Caliber Aorta descendens =

$$\sqrt[2]{\text{caliber ductus}^2 + \text{caliber Pars. comm. aortæ}^2}.$$

The aggregate measurement in twenty-two cases, where the three measurements are to be found and in which ductus and Pars. comm. aortæ are equal (Table I), is as follows: Ductus = 2.97 —; Pars. comm. aortæ = 2.97 —, and Aorta descendens = 3.83 + mm. Computed the latter vessel should read 4.14 + mm. This error, while but 0.31 mm. in the linear caliber, is equal to 18.6 per cent in carrying capacity. In other words, according to Ziegenspeck's figures,

TABLE I.

NUMBER.	CALIBER DUCTUS.	CALIBER PARS. COMM. AORTÆ.	CALIBER AORTA DESCENDENS. Ziegenspeck.	CALIBER AORTA DESCENDENS. Calculated.	ERROR IN MM.	(CALIBER AORTA DESCENDENS.) ² Ziegenspeck.	(CALIBER AORTA DESCENDENS.) ² Calculated.	PERCENT CARRYING CAPACITY. Ziegenspeck.	ERROR IN CARRYING CAPACITY.
1	1.5	1.5	1.7	2.1 +	-0.4 +	2.89	4.50	64.22	-35.78
3	2.0	2.0	3.0	2.8 +	+0.2 -	9.00	8.00	112.50	+12.50
4	2.0	2.0	3.0	2.8 +	-0.2 +	9.00	8.00	94.50	+15.50
21	2.0	2.0	2.6	2.8 +	+0.2 -	9.00	8.00	112.50	+12.50
17	2.3	2.3	3.0	3.2 +	-0.9 +	9.00	10.58	112.50	+12.50
9	2.3	2.3	3.0	3.2 +	-0.9 +	9.00	12.50	72.00	-14.94
11	2.5	2.5	3.0	3.5 +	-1.0 +	9.00	12.50	72.00	-28.00
14	2.5	2.5	3.0	3.5 +	-1.0 +	9.00	12.50	115.50	+15.50
18	2.5	2.5	3.0	3.5 +	-1.0 +	9.00	12.50	72.00	-28.00
2	3.0	3.0	3.5	4.2 +	-1.2 +	12.25	18.00	88.88	-31.95
10	3.0	3.0	3.5	4.2 +	-1.2 +	12.25	16.00	88.88	-11.12
15	3.0	3.0	3.5	4.2 +	-1.2 +	12.25	18.00	88.88	-31.95
19	3.0	3.0	4.0	4.2 +	-1.2 +	16.00	18.00	88.88	-11.12
23	3.0	3.0	4.0	4.2 +	-1.2 +	16.00	18.00	88.88	-11.12
29	3.0	3.0	4.0	4.2 +	-1.2 +	16.00	18.00	88.88	-11.12
30	3.0	3.0	4.0	4.2 +	-1.2 +	16.00	18.00	88.88	-11.12
16	3.5	3.5	4.0	4.9 +	-1.4 +	16.00	24.50	65.30	-34.70
25	3.5	3.5	4.0	4.9 +	-1.4 +	16.00	24.50	90.16	-9.84
27	3.5	3.5	4.7	4.9 +	-0.2 +	22.09	24.50	94.53	-5.47
24	4.0	4.0	5.5	5.6 +	-1.1 +	30.25	32.00	72.00	-28.00
32	5.0	5.0	6.0	7.1 +	-1.1 +	36.00	50.00	98.00	-2.00
33	5.0	5.0	7.0	7.1 +	-0.1 +	49.00	50.00		
	2.97—	2.97—	3.83+	4.14+	-0.31			81.37	-18.63

the Aorta descendens can carry away but 82 per cent of the blood fed to it by the ductus and descending aortic arch—unless the resistance in the descending aorta is less than in the carotid-subclavian system and in the right and left pulmonary arteries. If the Aorta descendens actually carries away one half of the contents of both ventricles, as Ziegenspeck maintains, then it is also possible to compute the caliber of the aortic and pulmonary stems—measurements which he unfortunately does not give us.

Furthermore, much depends on the accuracy in calibration of small vessels. If we select certain of the measurements, we find that individual variations between the actual and computed value of the Aorta descendens are extreme. In No. 1, for example, the carrying capacity of the descending aorta is 35 per cent less than calculated. In only three cases does he obtain the vessel slightly larger; in ten, it is smaller; and in nine, it is too small by about 31 per cent.

To test the validity of these measurements we selected two pigs at random, taken from the same uterus and hardened by formalin injection. Ring segments were cut out of the vessels named in Table II; the rings split and carefully straightened to avoid stretching. A linear measurement on the intima when divided by 3.1416 ought to give a relatively accurate calibration if this method can be employed, and if the vessel lumina are circular. According to Ziegenspeck, the following equations obtain:

1. Caliber Aorta descendens² = caliber ductus² + caliber of Pars. comm. aortæ².
2. Caliber Pulmonary stem² = caliber ductus² + caliber right pulmonary² + caliber left pulmonary².
3. Caliber Aorta descendens² = caliber aortic stem² + caliber pulmonary stem².

2

TABLE II.

	A			B		
Pulmonary stem	3.8	= 14.44	= 14.44	4.0	= 16.00	= 16.00
Ductus	2.6	= 7.76		2.2	= 4.84	
Right pulmonary	2.1	= 4.40	} = 14.72	1.9	= 3.61	} = 9.89
Left pulmonary	1.6	= 2.56		1.2	= 1.44	
Aortic stem	3.8	= 14.44	= 14.44	3.8	= 14.44	= 14.44
Pars comm. a.	3.0	= 9.00		3.0	= 9.00	
Aorta descendens	4.1	= 16.81	= 16.81	3.8	= 14.44	= 14.44

Equation 1. In A. 16. 8 : 16.76. In B. 14.44 : 13.84.

Equation 2. In A. 14.44 : 14.72. In B. 16.00 : 9.89.

Equation 3. In A. 15.81 : 14.44. In B. 14.44 : 15.22.

Equation 1 conforms nicely in pig A; in B an error of 3 per cent carrying capacity. Equation 2 conforms nicely in pig A; in B an error of 38 per cent carrying capacity. Equation 3. In pig A, the Aorta descendens is 16 per cent larger than necessary (carrying capacity), and in B, it is 5 per cent smaller than necessary. In all of these measurements the coronary circulation has not been taken into account. In any event the results will show that measurements of this character are valueless for exact conclusions because we must grant that:

1. The vessel lumina are exactly circular.
2. The vessel elasticity must be equal.
3. The expansion of these vessels must be equal in all directions.
4. The intrinsic vessel resistance must be the same.
5. The capillary resistance in all vessels must be equal or known.
6. The quantity of blood expelled by the two sides of the heart must be the same and the pressure exerted equal.
7. The vessels must undergo no particular change after death and fixation.

When all these points have been established, there are still a number of factors to be considered before we can arrive at definite conclusions. We, therefore, raise the question of reasonable doubt to Ziegenspeck's major premise, and state in opposition that we believe we can show that the Aorta descendens carries away more than half of the contents of both ventricles, and further, that the ductus carries more blood than the Pars communicans aortæ.

DATA OBTAINED FROM INJECTION.

It would be difficult, indeed, to grant that the relations of the blood currents in the living fetal heart could be studied in the dead animal, and this is more true in Ziegenspeck's experiments, because only one vein was injected and no attempt made therefore to repro-

duce, as far as it was possible, the life-like conditions. We have seen that Trew, Roederer, Sénac and others found that injected material did pass through the foramen ovale; Reid found that material injected into the inferior cava in the human embryo passed over entire to the left, or at least he did in one case, even when a simultaneous injection was carried out in the superior cava; Ziegenspeck finds that material injected into the umbilical vein passes equally to the right and left ventricles. We do not object to this as a finding, but we do not see how of itself it proves anything for the living heart under entirely different conditions, and minus the factor of auricular and ventricular aspiration that Ziegenspeck himself uses as an argument against the theory of Galen-Harvey.

We now come to a critical examination of Ziegenspeck's contention: "Das Blut, welches in einem Herzrhythmus das Herz durchströmt, wird gevierteilt. Die Hälfte wird von der V. cava inf. geliefert und gleichmässig auf den linken und rechten Vorhof verteilt. Jedes Viertel der Gesamtmenge mischt sich links mit der gleichen Menge aus den Lungenvenen, rechts mit der gleichen aus der V. cava sup. Diese Mischung: $\frac{1}{2}$ Cava inf., $\frac{1}{2}$ Cava sup. geht zu $\frac{1}{2}$ durch die Lungenarterien nach links zu $\frac{1}{2}$ unverbraucht in die Aorta descendens (durch den Ductus arteriosus). Die Mischung links geht ebenso zu $\frac{1}{2}$ unverbraucht durch das Schaltstück in die Aorta descendens, zu $\frac{1}{2}$ in den Oberkörper. Auch das Blut der V. cava inf. wird somit gevierteilt."

To state this proposition in our own way, grant that the ventricular capacity, right and left, equals a volume of say 4.0 cc., then the matter can be expressed in the form of an equation:

$$\begin{array}{rcl}
 \text{R. V.} = 4 & \left\{ \begin{array}{l} \text{Lungs} = 2 \dots\dots\dots \text{Pulmonary return} = 2 \\ \text{Ductus} = 2 \end{array} \right. & \text{L. V.} = 4 \\
 & \begin{array}{c} \text{Aorta descendens} = 4 = \text{Cava inf.} \\ \text{Pars. comm. aortæ} = 2 \end{array} & \begin{array}{c} \text{Left auricle} = 2 \\ \text{Right auricle} = 2 \end{array} \\
 \text{L. V.} = 4 & \left\{ \begin{array}{l} \text{Carotid - subclavian} = 2 \dots\dots\dots \text{Superior cava} = 2 \end{array} \right. & \text{R. V.} = 4
 \end{array}$$

Correlating this equation with Ziegenspeck's diagram (Fig. 1), we note that several important things have been omitted:

1. The coronary circulation—of the 4 cc. leaving the left ventricle a certain amount is returned to the right auricle but not through either inferior or superior cavæ. This, however, might be granted, practically speaking, in the return through the superior cava.

2. The azygos circulation—of the 4 cc. passing down the Aorta descendens a certain amount is not returned through the cava in-

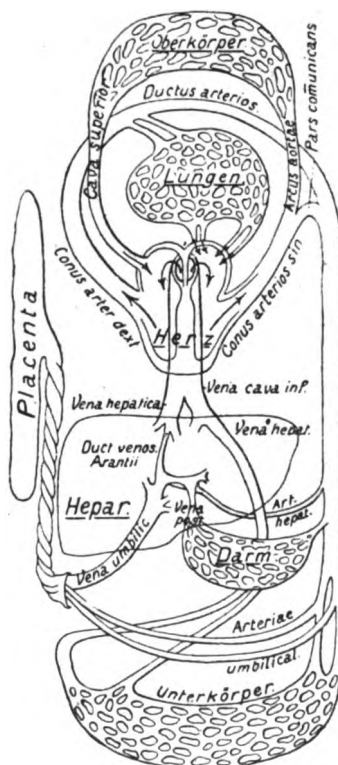


FIG. 1.

ferior but through the azygos system either to the cava superior or to the coronary sinus (pig). Results in 4 cc. minus returned through the inferior cava.

3. The lymphatic return of the entire region supplied through the Aorta descendens is returned to the heart through the superior cava. Results in 4 cc. minus returned through the inferior cava.

Leaving out a consideration of the bronchial system, the objections would mean that according to Ziegenspeck's contention and diagram, the return through the superior cava is greater than through the pulmonary veins, and second, that the cava inferior returns less than the 4 cc. necessary to fill both ventricles one half.

The only way to make this scheme a tenable one would be (inasmuch as the foramen ovale does not afford communication between the two auricles—Wolff theory), to abandon the exact division of blood and to grant that more than one half of the return through the cava inferior passes to the left. Here, however, we read, "Dass die linke Mündung der Vena cava inf. enger ist als die rechte ändert daran nichts", which is far from reassuring; and further, "Das Herz wirkt als Saugpumpe und jeder Ventrikel aspiriert in der Diastole das zu seiner völligen Füllung noch nötige Quantum aus der V. cava inferior." Now even granting the marked suction action of the ventricles (which we do not believe) inasmuch as the beat of the two sides is synchronous, the only way for the left ventricle to fill itself through the narrower channel would be to aspirate more markedly. But here Ziegenspeck answers the question himself by presenting Table II with thirty-three measurements to show that the right and left ventricular walls are of equal thickness, and by his assumption in his major premise that both ventricles exert an equal pressure during systole.

We are not able to see how this proposition may be made a feasible one, and also for reasons presented as the result of our own investigations must oppose "Das Gesetz der Halbierung des Blutes im Föetal-kreislauf". Further we do not see wherein Ziegenspeck is justified in his claim that he has simplified the description of the placental circulation, or wherein the anatomical findings of the Wolff school can lead directly to the assumption that the foramen ovale does not afford communication between the two auricles.

PERSONAL FINDINGS.

It became evident from the varying results obtained through observation and injection of the dead fetus, that if any further work

was to be done on the course of the blood through the fetal heart, it must be undertaken in the living animal, and with the placental circulation intact. The fetal pig was chosen because of the accessibility and abundance of material and the several propositions demanding an answer through the experimental method were considered as follows:

- I. Is the ventricular capacity an equal one in the fetal heart?
- II. Is the pressure exerted by each ventricle equal?
- III. What is the course of the blood entering the heart through the cava inferior?
- IV. What is the course of the blood entering the heart through the cava superior?

I. The capacity of the two ventricles in the fetal mammal has always been considered equal (note the exception in the Méry theory) because that is the condition in the normal adult heart and because of the necessity of this condition at birth. There appears, however, to be no experimental evidence on the question. Accordingly, the pig embryo was opened (see later) and a ligature slipped around the heart at the auriculo-ventricular sulcus with the idea that if the ligature was tightened at the completion of auricular systole, the aortic-pulmonary and auriculo-ventricular orifices would be occluded and the contents of the ventricles isolated. The experiment proved successful in two out of ten trials. The heart was next removed from the body, washed, the contents of each ventricle bled into separate vials and the volumes compared. Comparison of the two vials showed equal capacity as nearly as this rather primitive method permitted in both cases. There being no valid objection to equal ventricular capacity (generally accepted), the point was considered as settled in the affirmative. The two ventricles in the living fetal pig contain or at least expel equal quantities of blood.

II. The pressure exerted by the right and left ventricles in the fetus has also been considered equal, because both ventricles expel blood into the Aorta descendens, and secondly by observation, nicely shown in Ziegenspeck's table, because the right and left ventricular walls are equally well developed until after birth when the left ventricle wall hypertrophies rapidly. Our later experiments required

the simultaneous recovery of blood under identical conditions and to this end the following technique was employed:

Pieces of glass tubing about 10 cm. in length were carefully drawn in the flame to a fine connecting piece of about 1 mm. in diameter; laid aside to cool and then carefully broken at the point indicated (Fig. 2). This procedure resulted in pipettes of the same

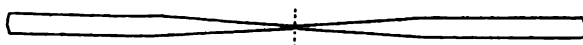


FIG. 2.

opening and, when fastened together with a small elastic band, permitted sufficient spreading to allow the pipettes to be passed one to either side of the ventricular septum and permitted their use as a single pipette. The opening in the pipettes was small enough to necessitate an actual pumping on the part of the ventricles, while the capillary attraction aided in holding the contained blood in place. This was further assisted by mouth pieces of rubber tubing which were pinched off on the withdrawal of the pipettes from the heart.

The beating heart was laid bare (see later) and the pipettes thrust one into each ventricle simultaneously. In all cases where the pipettes were properly introduced and where the heart continued to beat, the blood mounted progressively and evenly in both; proving to our satisfaction that the pressure exerted by the right and left sides is an equal one. Further there was little, if any, appreciable oscillation of the blood in the two pipettes which went to show that in the opened chest little aspirating action was manifested by the ventricles. The results, thus far, are in perfect harmony with what has been quite generally accepted and may be said to substantiate these views in an experimental way.

It was found that in the majority of pigs, the heart suffered but little inconvenience through the introduction of the pipettes and in some the heart beat quite rhythmically for many minutes even after they were withdrawn. Inasmuch as it was impossible to estimate how long it would take the blood to reach the heart from a given point, a requirement was set that the heart must beat at least five times after the introduction of the pipettes and that the blood

must mount evenly and progressively in both pipettes. Each pig used therefore directly controlled the point that the ventricles exerted an equal pressure.

Injection Experiments.

We have seen that the legitimate cry of artifact was raised by Born to the anatomical findings of Ziegenspeck, and that it may also be raised to all injection experiments on the dead animal even if the animal be used directly after death and all precautions taken to avoid undue pressure. The heart itself is no longer the active agent and there is no way of determining how much the contracture of the heart muscle may influence its normal intrinsic relations.

Technique. The following idea was carried out: to inject a non-irritant granular substance suspended in normal salt solution into a selected vein; to allow the blood current to propel these granules to the heart; to recover some of the blood from both beating ventricles under identical conditions; and to examine the blood recovered for the granules injected.

Stand was taken in the abattoir where the pig uteri were removed and dropped into a tank truck. The larger and uninjured uteri were selected and laid upon a table. Next a small incision was made into the uterine wall at some distance from the markedly vascular area and the incision widened by tearing to allow the escape of the pig. It was found that tearing through the uterine wall practically eliminated all hemorrhage and pigs were rejected if any amount of oozing occurred.

Injection was made only in those pigs in which the cord pulsation was strong. An ordinary hypodermic syringe was filled with corn-starch granules suspended in normal salt solution, the air expelled, and about one half of the syringe contents was injected slowly into the umbilical vein, some 5 cm. from the navel. The needle withdrawn, the pig was rapidly opened with a large blunt scissors by cutting through the length of the sternum and by a lateral cut through the abdominal wall just below the diaphragm. A blunt instrument was selected with the idea of tearing rather than cutting through the tissues and pigs were again rejected if anything further than

a slight oozing resulted from the incisions. Next the pericardium was incised and the paired pipettes thrust simultaneously into the two ventricles. An arbitrary requirement was established that the heart must beat at least five times after the introduction of the pipettes, giving a better chance of recovering the granules injected. The blood in the pipettes was immediately expelled into paired vials, marked right and left, containing a small quantity of half per cent acetic acid. The vials corked and shaken thoroughly. Later the vials were separated, and the contents diluted to an equal quantity with dilute acetic acid. Each was shaken a given number of times, and a small amount of fluid withdrawn by a pipette from the central area of the vials. Samples from the right and left sides were placed on one slide and compared under the microscope for the number of starch granules.

Objections.

1. The death of the mother. It is well known that pigs will live in the removed uterus for many hours after the death of the mother. In our experiments the time rarely exceeded half an hour and in some cases about fifteen minutes after the sow's death.

2. The contraction of the uterus. This was not marked but was present in some cases. We shall show later that this is not a serious objection to our results.

3. The artificial factors introduced in opening the chest and manipulating the heart. Granted present. The collapse of the lungs especially offers an abnormal condition which probably limits the pulmonary return.

4. The introduction of the pipettes. This is undoubtedly placing the heart under some disadvantage, but we do not consider the objection a serious one because only a small quantity of blood was withdrawn and because the heart showed no signs of interference for at least five beats.

5. The introduction of a foreign substance in the circulation. Cornstarch granules are non-irritant and non-toxic but are of sufficient size to plug the capillaries, hence the blood was obtained as soon as it reached the heart.

It will be seen from these objections to our method that it is practically impossible to reproduce the normal conditions in all details as they are found in the fetus in utero. All that we claim is that the artificial elements were avoided as far as facilities permitted, and that our procedure is an improvement on experiments made thus far. We at least allowed the blood stream to propel the granules through what appears to be the normal course of the blood in the fetal heart with a minimum of abnormal conditions imposed. The method can, therefore, not be called exact enough for definite proportions, and we make use of the term 'about equal' in this paper as a personal equation set within 10 per cent of difference in comparison of the two blood samples.

III. What is the course of the blood entering the heart through the cava inferior?

Injection of about one half of the contents of a hypodermic syringe filled with a suspension of cornstarch granules in normal salt solution was made into the umbilical vein about 5 cm. from the navel. The pig was opened immediately, and the blood recovered from the beating heart as in Experiment II. Seventeen paired samples were recovered which registered equal coloration on dilution to equal volumes, and these were examined. Five paired samples proved negative—no corn starch granules found in either ventricle and twelve paired samples were positive—starch granules present. In all twelve paired samples the number of granules proved to be 'about equal' on both sides.

The experiment proves beyond a doubt (as far as pig is concerned) that the von Haller-Sabatier theory is incorrect and that the objections of Williams, Peaslee and Macdonald were well taken. It seems to prove that the blood from the inferior cava is distributed about equally to the two ventricles, and is, therefore, in accordance with the Wolff theory or with the theory of Galen-Harvey. The former states that the blood from the inferior cava is split upon the limbus Vieussens and that the foramen ovale does not afford communication between the auricles; the latter assumes a small pulmonary return, a mixing of the blood of the two cavæ in the right auricle, and a passage of mixed blood through the foramen ovale.

It now remained to inject the superior cava—for if the granules did not pass through the foramen ovale, the Wolff theory was sustained; while if the granules were recovered from both ventricles, the theory of Galen-Harvey was substantiated.

IV. What is the course of the blood entering the heart through the cava superior?

This experiment was found more difficult than the preceding test. It was found almost impossible to open the chest the full length and expose the great veins at the root of the neck without injury to these structures. The insult offered proved to be greater and the death rate proportionately larger. Next only one or two drops could be injected into the superior cava to avoid undue pressure, and, when the needle was withdrawn, the unsupported vein tended to bleed freely. The time limit was reduced to one to two seconds from injection to introduction of the pipettes. Seven paired samples were finally obtained which registered equal coloration on dilution. One proved negative—no starch granules on either side, and six positive—starch granules present. In four, the number of granules on the right and left sides proved to be 'about equal;' in one, more were found on the left than on the right, and in one, more on one side than on the other (labels confused). In both of these samples the excess was easily 50 per cent.

The fact, however, that starch granules injected into the superior cava did pass through the foramen ovale in all cases where they were demonstrated at all showed conclusive evidence in favor of the theory of Galen-Harvey that the caval currents mix in the right auricle and that mixed blood passes from the right auricle into the left through the foramen ovale. Inasmuch as about ten seconds elapsed from the injection of the umbilical vein to the recovery of blood from the heart in Experiment III, and one to two seconds from the injection of the superior cava, it was thought possible to make a double injection in the same pig using colored granules in the one and colorless granules in the other injection. If both varieties of granules were found on both sides, the experiment would show that the currents mix in one and the same pig.

Pigs in this experiment were opened first and about ten seconds

allowed from the injection of the umbilical vein with colored granules (I-KI) to injection of the superior cava with colorless granules. Only six pigs lived through the requirements in two full mornings work, and of the six, three samples were lost owing to the hurry. Two paired samples were obtained and one from the left side (right pipette struck the septum). Superficial examination of these samples revealed the presence of both varieties of granules on both sides in the two and both varieties in the one from the left. There was of necessity a delay in counting, and when it was attempted some hours later, it was found that the iodine had diffused and colored a large proportion of the colorless granules so that a comparative count was impossible. The experiment, however, further substantiated the Galen-Harvey theory and opposed, therefore, all the more the Wolff theory.

The results from our experiment in the living embryo lead to the following statement: that the ventricular capacity and pressure is an equal one; that the foramen ovale does afford communication between the two auricles; that the blood of the two cavæ mixes in the right auricle; and that mixed blood passes through the foramen ovale. We agree, therefore, with the theory of Galen-Harvey and believe to have established it through experimental evidence.

It now remains to consider what objections may be raised to our results and wherein the evidence supports the Galen-Harvey theory as opposed to all other theories.

It will be seen from our results in the living pig embryo that about one half of the return through the superior and inferior cavæ passes through the foramen ovale into the left auricle. This fact might be interpreted in one of two ways if we grant, as we must, that the collapse of the lungs through opening the chest interferes with the pulmonary circulation—the passage of blood through other parts of the fetal body not necessarily being affected:

a. The pulmonary return is relatively free, as stated in the Wolff theory, and that the artificial factors (collapse of lungs and manipulation of the heart) are sufficient to practically prevent blood from passing through the lungs; or,

b. The lung circulation is relatively small in amount and that

the pulmonary return is reduced by the artificial conditions so that it might be well within the personal equation set in our experiments (10 per cent).

The first interpretation offers a serious objection to our results because those investigators favoring the Wolff theory will hold that if we interfere with a large pulmonary return (about one half [Wolff], exactly one half [Ziegenspeck] of the contents of the right ventricle), we also destroy the normal balance of return to the auricles through increase in flow through the cava inferior and through decrease in flow through the pulmonary veins. Hence, the normal position of limbus Vieussens to the orifice of the inferior cava and the function of the foramen ovale may be rendered false. This criticism we have foreseen and we, therefore, discuss the position of the Wolff theory rather fully.

The results of our first two experiments have confirmed the major premise of the Wolff theory that both ventricles expel the same amount of blood under the same pressure, and we now come to an examination of the physical laws underlying the flow of the blood through the arteries. Ziegenspeck based his measurements on the arguments that if the caliber of the ductus and Pars comm. aortæ was an equal one, they transmitted equal quantities of blood; that this quantity transmitted by each vessel was equal to one half of the contents of a ventricle; and that the Aorta descendens carried away one half of the contents of both ventricles. We stated in our objections to these propositions that we believed it might be shown that the ductus transmits more than the Pars comm. aortæ; and that both feed into the Aorta descendens more than one half of the contents of both ventricles.

If we can prove that the resistance to flow in the Pars comm. aortæ and in the ductus is less than in the branches of the aortic arch and in the right and left pulmonary arteries respectively, then we also prove that the Aorta descendens carries more blood than the caliber of its lumen would indicate, while the other branches convey relatively less. We believe we can substantiate the generally accepted idea that the placental area is the point of least resistance in the fetal circulation for the following reasons:

1. The two large umbilical arteries feed into one large umbilical vein—a proportion of lumina which would indicate that either the arteries are under lower pressure than usual, or the vein is under relatively higher pressure. In either case, it would present a low resistance in the placental capillaries.

2. The umbilical vein, practically of round lumen, transmits blood directly and indirectly into the intra-thoracic cava inferior without any marked increase in lumen of the latter vessel, showing that by far the larger proportion of blood passing down the Aorta descendens is returned through the umbilical vein.

3. The umbilical arteries and vein have a long and tortuous course through the jelly-like cord which probably offers little support to the vessel walls, and were not the placental resistance lower than the resistance in the vessels of the embryo body, little blood would pass through the umbilical vessels, whereas we know the reverse to be the case. It must be remembered that in human embryos the cord usually averages about 55 cm. at birth, and that the umbilical arteries may be reckoned on an average of 50 cm. longer than any other arteries in the fetal body, and the vein, while not proportionately long, is easily 40 cm. longer than any other vein. This distance of a little less than a metre represents an appreciable amount in terms of intrinsic vessel resistance.

4. There can be but little doubt that the contraction of the uterus must increase the resistance in the placental site and still the fetal heart is able to force the blood through the long course and quite freely. This is our answer to the objection that opening the uterus rendered false the circulatory condition in the fetal pig.

5. Taking Ziegenspeck's measurements at their face value if a 2.97—mm. ductus and Pars comm. aortæ feed into a 3.832 mm. Aorta descendens, then the resistance in the latter vessel must be considerably less than the resistance found in the lungs and carotid-subclavian vessels, for the lumen is too small to carry off the blood. It should read 4.14 + mm.

From these data we are able to assume with reasonable certainty that the resistance to flow in the placental area must be considerably less than in the fetal body, and that, therefore, until this resistance

is a known quantity, the lumen of the Aorta descendens is no criterion of its carrying capacity. We believe that the Aorta descendens carries more than one half of the contents of both ventricles, and believe this is not only a logical deduction but that it is confirmed by observation.

Conversely, if the circulation through the Aorta descendens is relatively free, then the blood flow through the carotid-subclavian and pulmonary arteries is relatively small. In other words, these two systems return less than one half of the contents of both ventricles. While this view is entirely contrary to Ziegenspeck's law of the equal division of blood, it is not entirely contrary to the Wolff theory of the splitting of the current of the inferior cava upon the limbus Vieussens. It will be necessary to substantiate our evidence from the injection experiments by an attempt to show clearly that the lung circulation is relatively smaller in amount than the circulation through the carotid-subclavian systems, or negatively, that the ductus carries more blood than the Pars comm. aortæ. The two points will be argued under separate headings, although they lead to the same result.

Evidence that the circulation through the lungs is relatively small in amount:

1. The histological appearance of the fetal lung, even when hardened in situ, does not substantiate the theory that large quantities of blood pass through the pulmonary circulation. The air sacs are collapsed, the capillaries are compressed and tortuous and possibly more numerous than elsewhere in the fetal body. Not only is the blood current interfered with directly in the capillary system, but the expansion of the vessels to the blood stream is limited.

2. The right and left pulmonary arteries are placed practically at right angles to the blood impact, while the blood wave passing around the aortic arch meets the carotid-subclavian vessels with their openings more nearly parallel to the current. Showing if the lumina of these vessels read alike, the carotid-subclavian arteries will receive a trifle more blood (the grain of truth in the Sabatier theory).

Evidence that the ductus conveys more blood than Pars comm. aortæ and that it carries more than one half of the contents of the right ventricle:

1. The laws governing the equal flow of fluid through pipes have certain limiting clauses; not only must be the 'head', the direct resistance at the pipe opening and the pipe lumen and character be the same, but the pipes must be of the same length and have the same course. Therefore, the Pars comm. aortæ will transmit less blood than the ductus, even if the caliber be circular and of the same diameter, because the course of the blood from the left ventricle is a longer one; because the course is curved as opposed to the relatively straight line to the ductus; and because the branches on the arch are more advantageously placed to interfere with the current.

2. If in our experiments we interfered with a large flow of blood through the lungs, then one of two things must have occurred:

- (a) We increased the pressure on the right side in order to force the excess of blood through the ductus, or
- (b) We decreased the amount of blood expelled by the right ventricle.

We have shown in our experiments that the pressure on the right and left side continued to remain the same, for the blood mounted progressively and equally in the pipettes when they were properly introduced and where the heart continued to beat. Inasmuch as no difference was observed in the character of the heart beat, we may infer that the ventricles continued to expel equal quantities of blood as demonstrated in Experiment I under the artificial conditions mentioned. If we grant that the lung circulation is free, the ductus carried away the excess without any appreciable effort on the part of the right ventricle; according to Ziegenspeck, the ductus would have to carry double the amount, and according to Wolff perhaps not quite double. If we grant that the circulation is relatively small, the ductus carried but little more than normally.

We, therefore, do not see any evidence that we interfered seriously with an alleged large amount of pulmonary return or that we over-supplied the vena cava inferior with blood. Further, waiving all this evidence aside, if we did increase the amount of return through the inferior cava, we also raised the pressure in that vein, and we still do not see why the limbus Vieussens should not divide the current in the manner demanded by the Wolff theory. If we inter-

ferred markedly with any of the return, it was that through the cava superior and this should if anything lessen the chances of that blood passing to the left.

If we now grant that the pulmonary return is relatively small in amount, then we can group the von Haller-Sabatier and the Wolff theories under one head, for in neither does the foramen ovale afford communication between the two auricles and in both the vena cava inferior must send an excess of blood to the left auricle to make up for the deficient pulmonary return. Against these theories we can present the view of Galen-Harvey that the foramen ovale does afford communication between the two auricles and that mixed blood in the right auricle passes through that opening to make up for the deficient pulmonary return. Which of these theories do the facts support?

Neither the von Haller-Sabatier nor the Wolff theory can account for the relatively good circulatory conditions found in embryos with bilocular and trilocular hearts; in the cases of incomplete separation of the ventral aortic stem into aorta and pulmonary artery; or in the anomalous cases where the lungs are supplied, in part, from the Aorta descendens. All of which conform to the Galen-Harvey theory.

For the Harvey theory, as opposed to all others, comes our evidence obtained in the living pig that in no case were cornstarch granules injected into the inferior or superior cavæ or both—not recovered from both sides of the heart. For the Harvey theory comes the simple explanation of a mixing of blood in the right auricle, and the passage of mixed blood through the foramen ovale to the left auricle. In this theory, we gain the point raised in the Wolff theory that no artery in the embryo contains arterial blood, without the extremely complicated and incorrect arrangement presented by that scheme.

We trust that this article carries conviction with it and that the coloring of diagrams of the fetal circulation to render the impossible theory of Sabatier clear to the student will hereafter be omitted. The arrows to indicate the course of the blood through the fetal heart may be replaced by the statement—the blood of the two caval

veins mixes in the right auricle, and mixed blood passes through the foramen ovale into the left auricle to make up for the deficient pulmonary return (the theory of Galen-Harvey).

PRELIMINARY NOTE ON THE REPTILIAN AND AMPHIBIAN
CIRCULATIONS.

Every article that has appeared since 1835 has been in favor of the proposition that no arteries in the mammalian embryo contain arterial blood. It would be fitting, therefore, to retrace our steps to the time of Harvey, Méry, Winslow and others. Here we find that the relations of the blood currents in the mammal were based largely on the turtle. In this animal, although the auricles are completely divided, the undivided ventricle lends itself to a similar scheme

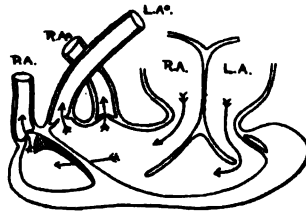


FIG. 3.

of the crossing of currents, and diagrams illustrating this condition of affairs have been presented. We present the scheme taken from Parker and Haswell after Huxley (Fig. 3), together with the following description: "From the cavum pulmonale arise the pulmonary artery, and from the cavum venosum, the two aortic arches. When the auricles contract the cavum venosum becomes filled with venous blood from the right auricle, and the cavum arteriosum with arterial blood from the left auricle; the cavum pulmonale becomes filled with venous blood which flows into it past the edges of the incomplete septum. When the ventricle contracts, its walls come in contact with the edges of the septum, and the cavum pulmonale becomes cut off from the rest of the ventricle. The further contraction consequently results in the venous blood of the cavum pulmonale being driven out through the pulmonary artery to the lungs, while the blood

that remains in the remainder of the ventricle (arterial and mixed) is compelled to pass out through the aorta (ae)." Here, as in the mammal, we find anatomical observation correlated with inferred physiological necessity and no direct experimental evidence; and here again comes the question "Does this actually occur?"

We present a preliminary report of our findings in some twenty-five turtles of three species. We do not offer the data for anything more than its face value, or do we present it as an exact result. The method was somewhat primitive, but the evidence derived is suggestive.

The carapace was removed under precautions to eliminate hemorrhage, the heart laid bare and kept moist.² The experiment was divided into three parts: (1) injection of cornstarch granules in normal salt solution into the right auricle; (2) into the left auricle; and (3) double injection of colored and colorless granules into the two auricles.

The blood was recovered under identical conditions in the following way: A double ligature was placed around the three vessels at the transverse pericardial sinus; the cornstarch-salt solution was introduced into the auricle during its diastole; the auricle allowed to contract, giving time to have the distal ligature ready to tie; when the ventricular contraction was well under way, the distal ligature was tied and immediately the proximal ligature—thereby isolating a segment of the blood in each of the three vessels. The ligated part was then removed and washed to avoid any granules which might have been in the ventricle, and each vessel bled into separate watch glasses containing a quantity of $\frac{1}{2}$ per cent acetic acid. Washing between incisions to avoid any mixing. Comparison of the three glasses containing the blood recovered from right and left aortæ and from pulmonary artery respectively revealed that, whether cornstarch granules were injected into the right or left auricle or both, they were always recovered from all three vessels. Comparative count proved rather indefinite, although in one case equal quantities were counted in each vessel.

²The writer expresses his obligation to S. C. Murphy for the careful assistance rendered and for the use of his modification of Ringer's solution.

Further experiments on larger animals must be undertaken before the exact proportions can be established. The results show, however, decidedly in favor of the statement that in the turtle the arteries contain mixed blood.

It now remained to investigate the evidence presented in the amphibian, to which can offer as yet no personal experiments. The usual descriptions, however, are as follows: "When the auricles contract, the blood from the left auricle, which has come in from the pulmonary vein and is therefore oxygenated, is forced into the left side of the ventricle, while the impure blood from the right auricle, which comes through the sinus venosus, pours into the right side and middle portion of the ventricle. The blood from these different sources is prevented from becoming mixed by being received into slit-like chambers in the ventricular wall. During the contraction of the ventricle, the impure blood, lying near the opening of the bulbus, naturally passes out first, while the pure pulmonary blood from the left side is forced out only toward the close of the ventricular contraction. When the ventricle first contracts, the wall of the bulbus cordis is relaxed, and the impure blood flows freely over the edge of the spiral valve into the left compartment, when it is free to issue through the pulmo-cutaneous arches through their common opening. Now the blood is under less pressure in the pulmo-cutaneous arches than in the others, because its route is shorter and there are no impediments to its flow. The blood first issuing from the heart takes the line of least resistance, namely, the pulmo-cutaneous arches, and is forced through the first two pairs of arches only when it has no easier avenue of escape." (Holmes.)

Here are two definite statements, to which we may raise the plea of reasonable doubt: "Is the pulmo-cutaneous system really under less pressure and does it actually receive blood first?" With all preparations made to investigate this phase of the problem, we accidentally came across an article by Gompertz, who made simultaneous tracings from the two vessels and found that the curve in the aorta agreed with that in the pulmonary both for synchrony and for pressure. This statement again would sustain the objection made to the identity of currents in the amphibian circulation.

CONCLUSIONS.

1. The capacity of the right and left fetal ventricles is equal.
2. The pressure exerted by the right and left fetal ventricles is also an equal one.
3. The blood entering the heart through the superior and inferior cavæ mixes in the right auricle.
4. The foramen ovale affords communication between the two auricles.
5. Enough mixed blood passes from the right auricle into the left through the foramen ovale to make up for deficient pulmonary return.
6. The pulmonary return during fetal life is relatively small in amount, and probably does not exceed one fifth of the capacity of the ventricle.
7. The ductus carries more blood than the descending aortic arch; probably the proportion of 4-3 is not far from accurate.
8. The Aorta descendens, being under lower resistance, transmits more blood than the caliber of its lumen would indicate and the greater part of its blood passes out through the umbilical arteries.
9. No artery in the fetus contains pure arterial blood—all contain mixed blood.
10. We oppose the theory of von Haller-Sabatier and also the theory of Wolff and Ziegenspeck.
11. We substantiate the theory of Galen-Harvey.
12. We oppose the theory that the pulmonary artery in the turtle transmits only venous blood and hold for a mixture of blood in the common ventricle as opposed to Brücke's view.
13. We believe there is evidence for a mixing of blood in the amphibian ventricle or in the vessels or in both.
14. We believe that the closed circulation of an arterial and a venous blood is first found in the mammal and bird after birth; in the fetal mammal and bird; and in the reptile and amphibian we believe that the circulation is one of mixed blood. In the fetal mammal and bird, the mixing takes place in the right auricle; in the reptile, in the common ventricle or, where the ventricle is more completely divided, in the arterial orifices or in the foramen Panizzæ or in both;

in the amphibian, the mixing occurs in the common ventricle, in the vessels or in both.

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A METHOD OF POLISHING FROZEN SECTIONS.

BY

JOSEPH P. TUNIS.

In order to secure a series of clean cut sections of the adult human head for the demonstration of some of the anatomical relations of the accessory sinuses of the nose, the following method was found most satisfactory. It consists in polishing sawn sections, while still frozen hard, on a rapidly revolving wooden wheel wet with water and finely powdered pumice stone. A similar process is employed for beveling glass.

After employing this method, for more than two years, with a great variety of material, the results have been so uniformly successful as to warrant a detailed report. Connective tissue, muscles, bone and teeth polish with equal facility and smoothness. The resulting surfaces have the appearance of having been cut with a sharp knife.

Having secured a good adult head, it should be well frozen in a near-by refrigerating plant or during cold weather in the open. The sections, either frontal or horizontal, should then be sawn in the usual way by hand or by using the band-saw. The latter is much the quicker and easier proceeding. Whichever course is adopted, the section should be polished before it has a chance to thaw on a rapidly revolving wooden wheel (Fig. 1). This wheel must be run by power, horizontally, while a mixture of water and finely powdered pumice stone is playing constantly upon it. Heavy woolen gloves are useful and greasing the hands with vaseline, an advantage if many sections are to be polished at one time. Some little experience will be necessary to familiarize the operator with the proper use of the polishing machine. Plenty of pumice should be on hand, as one section may require a pound or more. It is best, therefore, to purchase the pumice in bulk, as the fine pumice supplied to dentists

in small cylindrical boxes does not mix well with water, and is not to be compared with the commercial variety.

As soon as the section begins to thaw, it should be frozen again, as a soft specimen is quickly spoilt. This is due to the fact that the bones polish much more readily than the softer tissues. If it is desired to polish both sides of a specimen, it is usually necessary to freeze again after one side is finished. This refreezing, however, often detracts from the clean cut appearance of the finished surface, especially if the section is not immersed in water before it is frozen for the second time. If the section has a tendency to float above the surface in the freezing pan weighting with a strip of sheet lead is an advantage. A series of numbered pans make it easier to keep track of the sections.

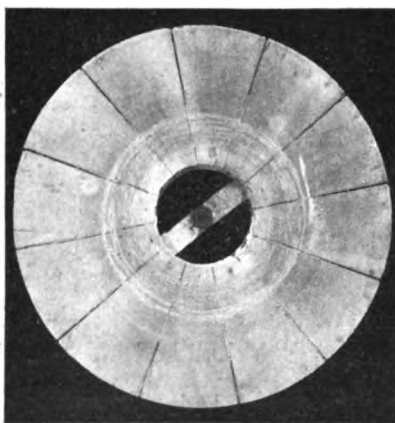


FIG. 1.—Wooden wheel for polishing frozen sections.

Fig. 2 shows photographs of the eighth section, made from the occiput forward, of a series from a woman's head (aged about seventy). They were made on a band saw and were each about half an inch thick. The anterior surface (Fig. 2, A) was not polished while the posterior surface (Fig. 2, B) was. A comparison of the surfaces illustrates the advantage of the method. Tracts in the spinal cord, or the distribution of the white and grey matter of the brain

can be demonstrated in this way. In order to secure the best results with such material, however, the brain must be specially prepared.

To illustrate the anatomy of any particular part of the head, a good preliminary section having been secured, it would be an easy matter to photograph that surface, polish a little deeper, make a second photograph, polish again and so continue until a series of photographs, of the region desired, would have been made. The only objection to this plan would be that only the last polished surface would remain for preservation.

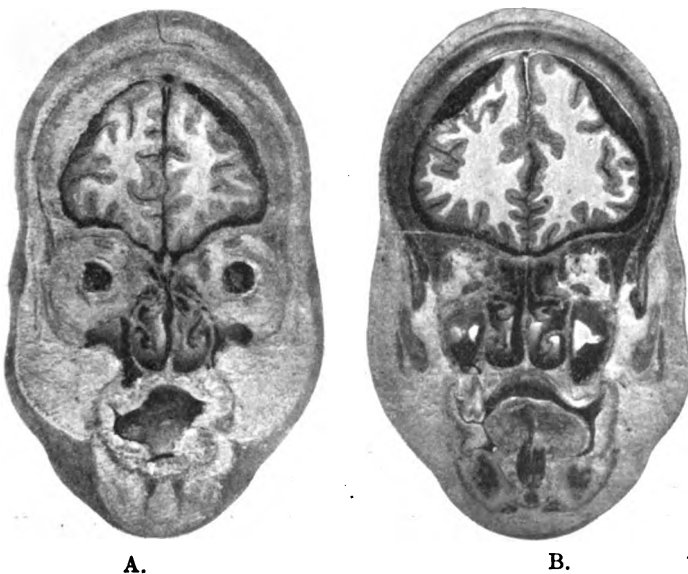


FIG. 2.—A section of the human head. A, Anterior surface, not polished. B, Posterior surface, polished.

The most satisfactory plan to adopt in preserving a series of sections that I have found is to place them in a large jar horizontally, in a four per cent solution of formaline, with pieces of ordinary window glass between them. In this way any distortion of the section is prevented and they may be kept indefinitely for future reference. Kept in formaline, however, they will blanch more and more, so that the best photographs are obtained as soon as the specimen has

been polished. The wooden wheel shown in Fig. 1 was twenty-nine and a quarter inches in diameter, one and three quarters inches thick. A considerably smaller wheel would have answered the purpose just as well.

As far as I can determine from a careful search through the literature of this subject, no report has been published of any similar attempt to polish the frozen surfaces of sections. For the use of all the needed apparatus I am indebted to the Wistar Institute.

Received for publication, October 27, 1908.

A SLIDEHOLDER FOR SERIAL WORK.

BY

H. E. RADASCH.

From the Anatomical Laboratory of the Jefferson Medical College.

Although a number of slideholders have been described, nothing seemingly suitable for large 2 by 3 inch slides, used in serial embryologic work, has been suggested. The writer desires to present an apparatus that is not only light and cheap, but that can be readily constructed by any one. The holders are made of thin aluminium, this metal having proved satisfactory from all standpoints.

A strip about $1/75$ th of an inch in thickness and measuring $6\frac{1}{4}$ by $2\frac{3}{4}$ inches is utilized for the base and sides. Each end of this strip is then nicked $\frac{1}{4}$ th inch deep and $\frac{1}{8}$ th wide for ten slides, as shown in Fig. 1; it is then bent at aa, bb, and a'a' and b'b' to assume the shape of Fig. 2. The distance bb' should be $3\frac{1}{8}$ th inches. Another piece of the metal $3\frac{1}{4}$ th inches long and $\frac{1}{2}$ inch wide is then nicked in the same way, having a $\frac{1}{4}$ th inch nick at each end at which place the metal is to be used as a clamp (Fig. 3, beyond cd). This strip is then bent at right angles at cc', then at cd and c'd'

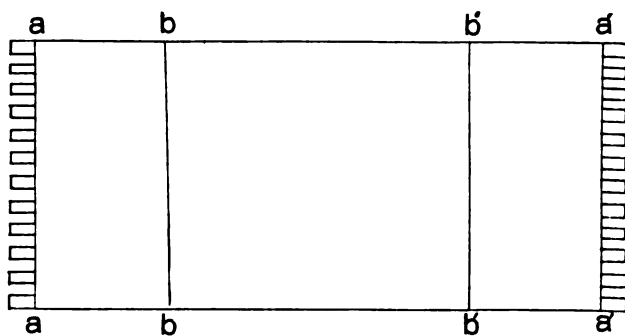


FIG. 1.

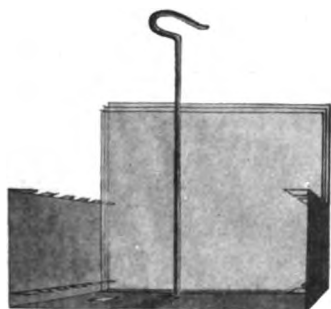


FIG. 2.

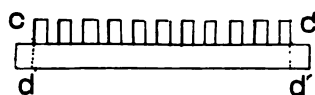


FIG. 3.



FIG. 4.

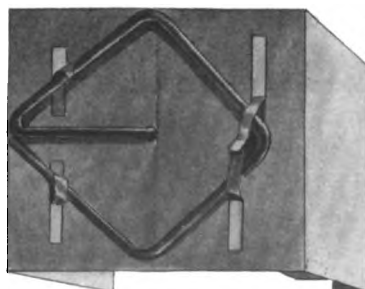


FIG. 5.

at an opposite right angle, as illustrated in Fig. 4; it is then placed at the base of the uprights of the main part and clamped into place, as seen in Fig. 2. These strips serve to support the lower edges of the slides. The base is then opened in four places, as seen in Fig. 5, and a handle and support of No. 10 aluminium wire is bent as in Fig. 5; the end is carried through a hole in the center of the base and a hook formed at its free end. This wire support is clamped into place by means of the strips cut out of the base, the openings left will serve as points of drainage for the space between the slides, when the trays are removed from one solution to another.

This holder is suitable for all ordinary solutions. When iodine is used, the trays must not be left in too long, as prolonged action of iodine tends to corrode the metal, as the writer has found by previous tests; this, however, is a matter of hours. If acid alcohol is used, the same precautions must be observed. With proper care these trays will last indefinitely. The first set made is still in use, although the trays have seen active service for over three years and no corrosion has been noted.

In order to utilize the least possible space and solution, the writer finds that the pint Barclay candy jars are admirably adapted and serve well as stain jars. With half a dozen trays and about eight jars for the various stains and wash solutions it is no difficult matter to carry through fifty slides in a few hours. The excess of stains and other fluids is always washed off by the use of a washbottle of alcohol or water, as the case indicates, before placing the trays in the succeeding jars. The step of clearing, however, the writer prefers to carry out on the table and upon fewer slides than ten each time.

Received for publication, January 23, 1909.

BOOK REVIEWS.

A LABORATORY GUIDE FOR HISTOLOGY. Laboratory Outlines for the Study of Histology and Microscopic Anatomy by Irving Hardesty, A.B., Ph.D., Associate Professor of Anatomy in the University of California. With a Chapter on Laboratory Drawing by Adelbert Watts Lee, M.D., Assistant in Anatomy in the University of California. vi + 193 pages, 30 illustrations, 2 colored. Philadelphia, P. Backiston's Son & Co. Cloth, \$1.50 net.

How best to lay before the student in the laboratory the work to be done, with the greatest economy of time and effort for teacher and the best educational result to the student, is a problem which every laboratory teacher meets and which is solved differently according to the peculiar ideas and ideals of each teacher. Perhaps, the most fundamental question involved is to what degree it is best to provide specific directions as a guide to the student, and one of the greatest dangers that will appeal to many is the thoughtless following of too specific directions by the student, in order to obtain the required results without any real appreciation of the purpose of the experiment or outlined work; the less the student is made to think, the less are the results attained his own, and in corresponding degree the chief educational value of laboratory work falls. The more individual and personal the laboratory instruction, therefore, and the less detailed and specific the general directions, the less will this defect in laboratory instruction be apparent. As a rule, however, individual instruction makes greater demands on the instructing staff, requires more of the student's time and is less easily carried out as the number of students increases. Particularly is this true in such a subject as Histology and some form of printed laboratory directions, bound or as separate sheets, has seemed to several teachers in this field almost a necessity when the number of students is large.

When such directions are put out in printed form as in the case of the book here reviewed, the value of the work is increased if sufficiently specific directions can be presented with a flexibility and adaptability that will make them serviceable in other years and other institutions, and this the author has attained with a marked degree of success.

The plan of the work appeals to the reviewer as excellent: to spare the student all unnecessary technique and yet permit him to gain a certain knowledge of general methods; to give him direct contact with the tissues and organs of the body by means of preparations uniformly and carefully made which become the property of the student; to furnish a correct idea of the natural appearance of tissues by means of their examination in the fresh state; to attempt to bridge the unnatural gap too often left between the gross and microscopic anatomy by providing for a preliminary examination or dissection of the organ as a whole.

The laboratory directions proper are presented in twelve chapters as outlines or papers (submitted as reports) as they are termed. Each chapter is closed with a bibliography intended to present the more important papers and monographs in the field covered by that particular outline to be made use of in collateral reading. In the various outlines the selection of the preparations to be studied is on the whole excellent and the directions to the student concise. Nearly every preparation is to be drawn or sketched, while numerous questions are introduced which are of distinct value in overcoming the defect inherent in specific laboratory directions. These twelve outlines are designed for a year's laboratory course of three weekly periods of three hours each, the whole being easily divided into three portions: (*a*) Histology, (*b*) Microscopic Anatomy, (*c*) Neurology. These may be given together (as in the institution for which the guide was primarily designed) or as separate courses if necessary. To adapt it to shorter courses, the omission of some of the preparations is suggested.

The outlines for the laboratory work are preceded by a chapter on laboratory drawing and are followed by one on technique and the care of the microtome knife. The first of these, by Dr. A. W.

Lee, is, as far as the reviewer knows, unique and of distinct value, not only, or perhaps principally, to the general student but to the advanced student as well, who must in too many laboratories provide for his own illustration and for whom the suggestions will be very helpful. As a whole the guide presents a good laboratory course in Histology and Microscopic Anatomy, and it should be quite generally useful. The rather frequent typographic errors will doubtless be corrected in a second edition.

B. F. Kingsbury.

Received for publication, January 23, 1909.

NOTES.

In order to encourage the spirit and method of scientific investigation among students of medicine, the University of Chicago offers three scholarships for the session of 1909-10 to be awarded to applicants presenting the best thesis in any of the sciences fundamental to medicine. It is to be hoped that the students who receive these scholarships, as well as other medical students, will thus be encouraged to continue, in their medical course, independent work in anatomy, physiology or pathology, for we are much in need of specialists in these branches who are investigators.

Students of ability who have had a taste of scientific work in physics, chemistry or biology, before they begin the study of medicine are best fitted to undertake such work in the medical course, and since the latter is very flexible at the University of Chicago, the authorities there wisely encouraged scientific work early in the medical course. We sincerely hope that their plan will be adopted by the better medical schools elsewhere, for only by a more liberal medical course can we hope to produce a sufficient number of trained anatomists, as well as of scientific medical men generally.

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No. 3

A HISTOLOGICAL STUDY OF SENSORY GANGLIA.¹

BY

MARTIN R. CHASE.

The researches on sensory ganglia before 1875 established the fact that the predominating type of ganglion cell is, in fishes, bipolar, and in higher vertebrates, unipolar.

In 1875 Ranvier demonstrated that the single process of unipolar cells divides by a T-shaped formation into two branches, one of which goes to the central nervous system, and one to the periphery. Later it was shown (Key and Retzius, '76, Retzius, '80, Lenhossék, '86) that the unbranched process of unipolar cells is the equivalent of the two processes of a bipolar cell.

Freud, in 1878, demonstrated that the ganglion cells of *Petromyzon* are both bipolar and unipolar, and he found a complete series of intermediate forms connecting these two types.

Retzius, in 1880, first pointed out that in many forms, particularly mammals, the axone of unipolar cells enters into a more or less complicated spiral formation, the initial glomerulus, immediately upon leaving the cell.

With the introduction of the Golgi and methylene blue methods, began a series of investigations that yielded important results.

Retzius, in 1890, demonstrated by the latter method a complete series of transformation stages from oppositipolar to unipolar cells in *Myxine*.

¹Contribution from the Zoölogical Laboratory of Northwestern University, Evanston, Ill., under the direction of William A. Locy.

Von Lenhossék, in 1892, found in his work on the spinal ganglia of *Pristiurus* embryos by the Golgi method, that, while the great majority of the ganglion cells were bipolar, a few unipolar forms and intermediate stages were present. He makes the point that the peripheral process of unipolar and intermediate forms enter the dorsal ramus of the spinal nerve.

Disse, '93, Cajal, '93, Von Lenhossék, '94, and Spiras, '95, reported the finding of multipolar cells in the spinal ganglia of chick and mammalian embryos. These cells seem to be transitory in nature.

Dogiel, '96, '97, '98, published the accounts of his studies of the spinal ganglia of mammals by the methylene blue method. He found besides the typical form of unipolar cells (Type I) a new shape (Type II). The single process of this latter type divides at the first node into 2-4 finer fibers, which, dividing repeatedly, diverge over the ganglion, and end by forming pericapsular and pericellular plexuses about cells of Type I. He also traces sympathetic fibers from the anterior roots to their termination in basket-like plexuses about cells of Type II. Thus sympathetic fibers come directly into relation with cells of Type II, and through them with Type I. He finds typical sympathetic (multipolar) cells in ganglia.

Other workers (Cajal and Oloriz, '98, Kamkoff, '97) have confirmed Dogiel's description of pericellular plexuses, but not that of cells of Type II.

Our knowledge of sensory ganglia has been much increased by the recent introduction of the reduced silver nitrate method of Ramon y Cajal, who in the *Ergebnisse*, etc., for 1906 gives a good review of the work done by this method to that time. In general, the work of Retzius, Dogiel, Cajal and others is confirmed, but many new details are added. Particularly to be mentioned are fenestration of ganglion cells, and the presence of accessory processes terminating in end bulbs.

Diagrammatically considered, the fenestrated type cell is characterized by protoplasmic processes, arranged in a netlike apparatus more or less complicated, by means of which a part or even the entire periphery of the cell is broken up into a system of anastomosing

fibers, which for the greater part go into the formation of the axone. Often there are slings which connect different parts of the cell-body and are independent of the axone. It should be noted that some of this work was anticipated by Daae, who in 1888 described the formation of the axone in the spinal ganglia of the horse, by means of the union of a varying number of roots arising from different parts of the cell.

Cells with bulbed processes. This type of ganglion cells was first described by Huber in 1896 in amphibians, and was re-found by Cajal in 1904 in man and larger mammals. Fine fibers arise from the cell-body or the axone of a regular glomerulated cell and end with rounded or oval bulbs on the cell-body, among the mantle cells, or on the inner surface of the capsule. Usually these processes are entirely within the capsule, but in some cases they pierce the capsule and end among the ganglion cells.

G. Levi, in 1906, found that the cells of the cerebrospinal ganglia of *Chelonia* are provided with two or three prolongations, varying from large lobes united to the nucleated portion of the cell by broad protoplasmic bridges, to fine fibrils ending with small bulbs. He observed that the latter were often numerous, and often by anastomosis formed a complicated system.

In his study of Selachians, Levi ('06) found the bipolar type of spinal ganglion cell in great majority, with rare unipolar and intermediate forms. Occasional cells showed short thick fibers arising from the cell-body, or from the axones, which were normal, and ending usually within the capsule.

In Teleosts, his observations show that transition and unipolar cells are more numerous. The accessory processes are sometimes fine non-anastomosing fibers, which form a sort of wreath about the periphery of the cell. In other cases they are coarser, and by anastomosis give rise to a condition similar to fenestration in mammalian ganglion cells. In some cases Levi thought he saw plexuses of sympathetic origin in continuity with accessory fibers from cells, but some doubt as to this observation is expressed by Cajal, who examined the same preparations.

Levi ('07) also considers fenestration and bulbed processes in mammals and deals with their development.

V. Lenhossék's observations by the silver method confirm those of Cajal and Levi.

According to recent developments (Kohn, '07) the mantle cells are developed from the ganglionic anlage and are consequently of ectodermal origin, rather than of connective tissue origin.

OBSERVATIONS.

The observations which follow were begun at the suggestion of Professor William A. Locy, and were carried on during 1907-1908 in the Zoölogical Laboratory of Northwestern University.

I wish to thank Dr. Locy for assistance at all stages of the work.

Material, etc. The material used was embryos of *Squalus acanthias* of about 16-20 cm length, and adult brains of *Mustelus canis*, fixed and preserved in formalin. A short study was also made of the spinal and Gasserian ganglia of certain mammals.

The ganglia of *Squalus acanthias* embryos were studied by sections, and by maceration and teasing. The best results were obtained by Cajal's reduced silver nitrate method, which was also applied to the mammalian material. (For this method see Cajal's article in the *Ergebnisse*, etc., for 1906, or v. Lenhossék's article in *Archiv f. mik. Anat.*, Bd. 68.)

A. *Selachians.*

General Comments. The ganglia especially studied in the Selachian material were the ganglia of the Ninth and Tenth cerebral nerves. The latter nerve is composed of several branches which preserve their identity, although bound for some distance in the same sheath of connective tissue. There are four of these branches which supply the gill slits, a branch to the lateral line organs, and a visceral branch, each with its individual ganglion.

As is well known, the ganglia, as a whole, are enveloped in a connective tissue sheath, a continuation of the epineurium of nerves. This sheath continues into the interior of the ganglion as the perineurium, surrounding the bundles of nerve cells and fibers, and as the endoneurium encloses the individual cells (capsule and fibers (fiber sheath)).

The connective tissue is not strongly developed in the ganglia of specimens of 16-17 cm. length, and the cells and processes are in close proximity to each other. The ganglion cells are quite evenly distributed throughout the ganglion, among the nerve fibers. Owing to the direct manner in which the processes leave the cells, the arrangement is such that in general the fibers and their cells lie in a direct course.

The cells are enclosed in a connective tissue capsule (Figs. 11, 12, Cap.) which takes the form of a thin structureless membrane. In sections the cells were contracted away from the capsule by the action of the reagents. (Figs. 11 to 13.)

On the interior of the capsule, and in the fresh condition pressing directly upon the cell body, are a number—4 to 6 or more—of round or oval nuclei, the nuclei of the mantle cells. (Figs. 3, 11, 12, 13, M. c.) These cells are also known as capsule cells, but the designation "mantle cells" seems the better term inasmuch as they are developed independently of the capsule.

On the interior of the sheath of the nerve fiber are found elongated fiat nuclei, the nuclei of the Sheath of Schwann, S. c. Figs. 1, 2 and 6. They are similar in structure to the nuclei of mantle cells.

The ganglion of the ninth nerve of Squalus Embryos. Study of macerated material was instructive as to the nature of the nervous elements of the ganglion. Such preparations demonstrated that by far the most prevalent type of nerve cell is the bipolar form. The cell body is somewhat elongated in the long axis of the ganglion, being oval or spindle-shaped, and from each pole is given off a process. (Figs. 1 to 3, c.p., p.p.) Figs. 2 and 3 are good illustrations of oppositipolar cells, that is, cells whose two processes arise from directly opposite poles.

But the oppositipolar form is not the invariable one. Cells were found which form a series from bipolar to unipolar cells similar to those described by Freud for *Petromyzon*, Retzius for *Myxine*, and Lenhossék for *Pristiurus* embryos.

The first stage in this transformation series is a cell, one of whose processes leans a little to one side, destroying the symmetrical shape of the cell body. Further approach of the processes toward one

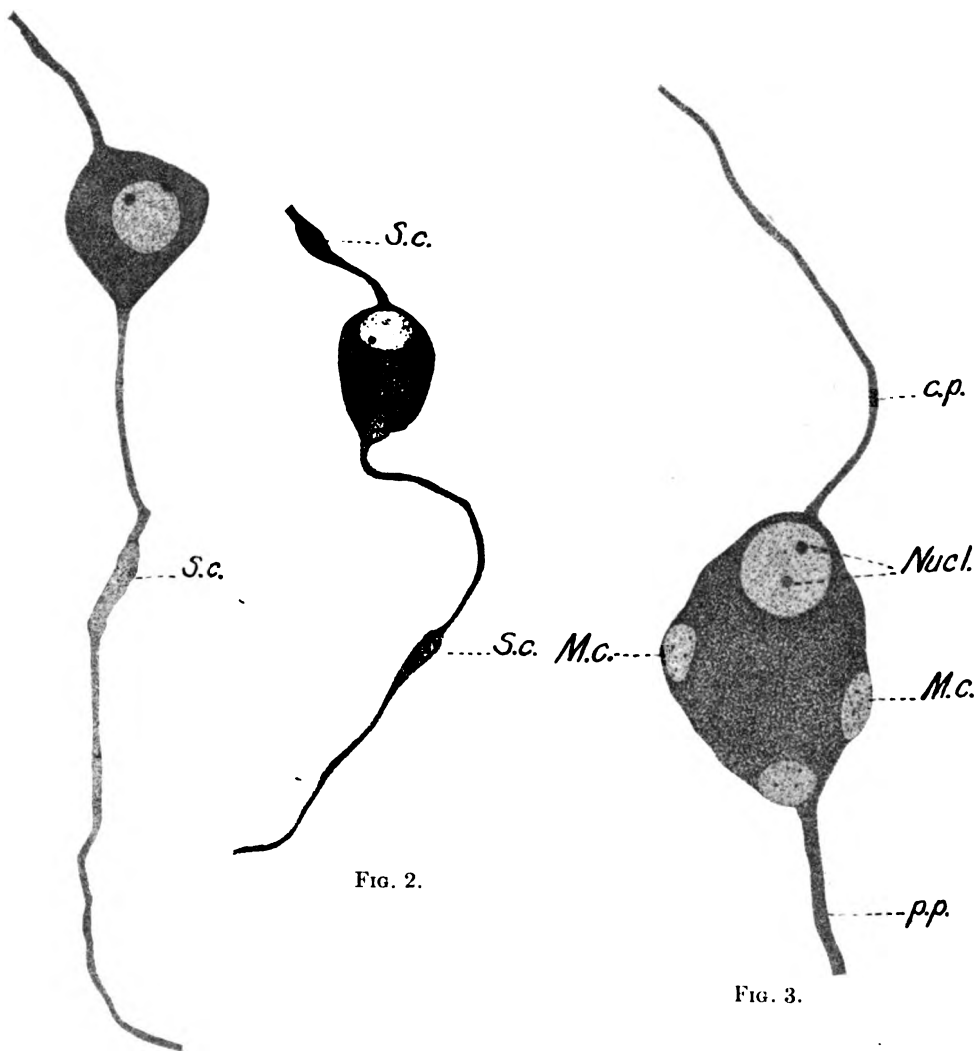


FIG. 1.

FIG. 1. Bipolar cell from a teased ganglion of the Ninth Cerebral Nerve of a *Squalus acanthias* embryo of about 16 cm. length. $\times 260$.

FIG. 2. Bipolar cell from a preparation similar to Fig. 1. $\times 260$, S.c., Cells of sheath of Schwann.

FIG. 3. Bipolar cell from a similar preparation. $\times 530$. M. c., mantle cells. c. p. central process. pp. peripheral process. nucl, nucleolus.

another results in the assumption by the cell-body of a still more asymmetrical position with reference to the origins of the axones. Fig. 4.

In Figs. 5 and 6 the origins are progressively nearer to each other. From this stage to that seen in Figs. 7 and 8 is but a short step.

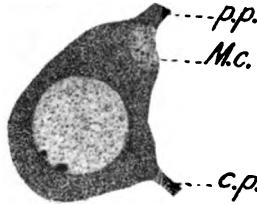


FIG. 4. Intermediate form from a teased ganglion of *Squalus* embryo. $\times 530$.

Here the processes have a common origin in the short thick axone, (ax.) dividing almost at once into two branches, p. p. and c. p.

Lengthening of the common origin into a more slender, true nerve fiber gives the final step in the process of unipolarization (Fig. 9). Here the single axone (ax.) leaves from the side of the cell body, dividing after a relatively long course into two fibers of almost equal

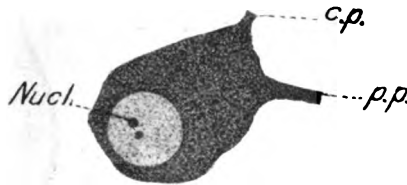


FIG. 5. More advanced intermediate form from the same preparation as Fig. 4. $\times 530$.

thickness. The unipolar cells were seldom seen, although many intermediate forms and quite a large number similar to Figs. 6 and 7 were found.

The following enumeration, the result of careful count of the cells in one slide, gives an idea of the proportions of the different elements:

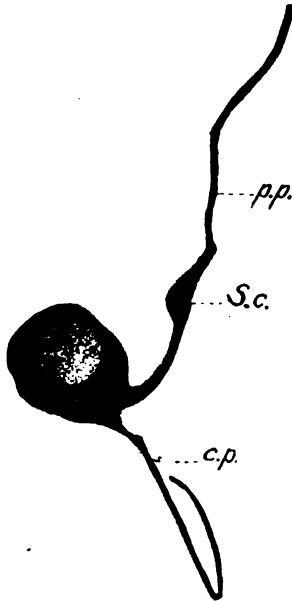


FIG. 6.

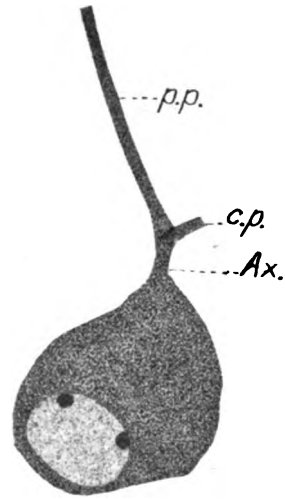


FIG. 8.

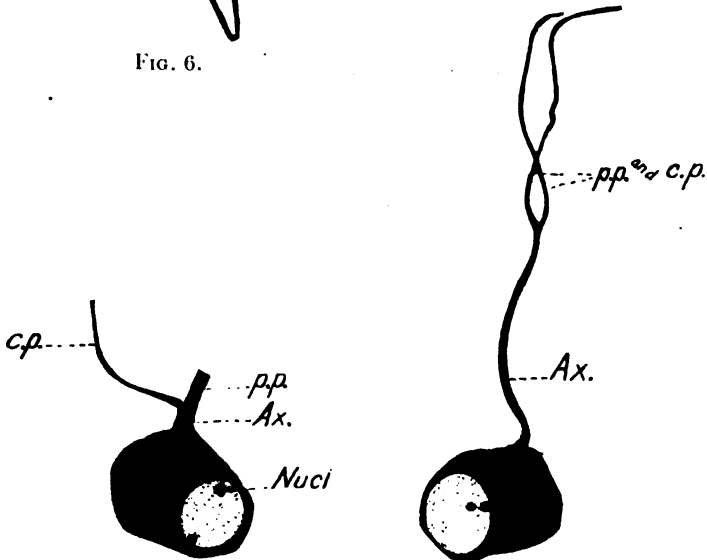


FIG. 7.

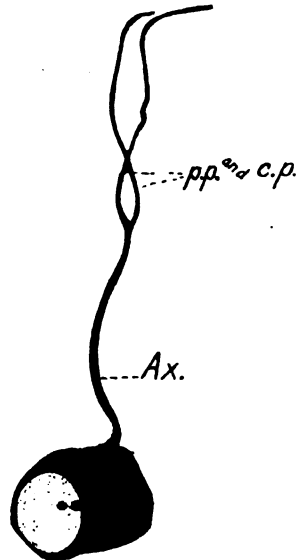


FIG. 9.

FIG. 6. Intermediate stage from ninth ganglion of the same individual as Fig. 4. $\times 530$.

FIG. 7. Early unipolar cell from same preparation as Fig. 6. $\times 530$.

FIG. 8. Early unipolar cell from same preparation as Fig. 6. $\times 530$.

FIG. 9. Unipolar cell from same preparation as Fig. 6. $\times 530$.

Cells undoubtedly bipolar	208	50.6%
Cells showing one process	124	30.0%
Cells broken or uncertain	77	19.0%
Unipolar cells	125%

Of the 208 bipolar cells, 20 were intermediate forms of various stages. This does not include all which departed slightly from oppositipolar condition. Of those classed as having one process, the majority undoubtedly must be interpreted as mangled bipolar cells, but some must be considered unipolar cells whose process has been broken off back of the bifurcation.

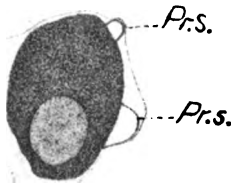


FIG. 10. Cell from a reduced silver preparation of the ganglion of the Ninth nerve of *Squalus* embryo, showing protoplasmic slings, Pr. s. $\times 530$.

In the majority of the cells drawn (Figs. 3 and 4 to 8) it will be noted that one process (p. p.) is of greater thickness than the other (c. p.). This is in conformity with the results of many writers who have found the peripheral process much thicker than the central.

The transition series above described is confirmed by the reduced silver nitrate method. Silver preparations show that while unipolar and intermediate stages are mainly located about the periphery of the ganglion, they may be found in any portion of it, and their processes have the distribution normal to bipolar cells. As stated in the review of the literature, v. Lenhossék finds in the spinal ganglia of *Pristiurus* embryos that these forms send their peripheral processes into the dorsal ramus.

Cells with protoplasmic slings. The silver method shows also the presence of cells with structures similar to those found in the adult forms of other animals. These cells exhibit fine protoplasmic processes which after a short curved course return to the cell at a short

distance from their origin, describing a sort of half circle. Fig. 10 illustrates such a cell. So far as seen the accessory processes in specimens of 16-20 cm. have formed closed slings, but it is supposed that they correspond to the complicated structures found in the adult.

Nucleus. The nucleus is relatively large and varies much in

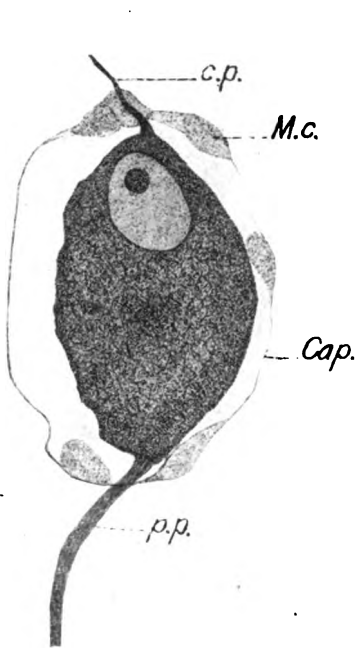


FIG. 11.

FIG. 11. Bipolar cell from a reduced silver preparation of the Tenth ganglion of a *Squalus* embryo 17 cm. long. $\times 530$.

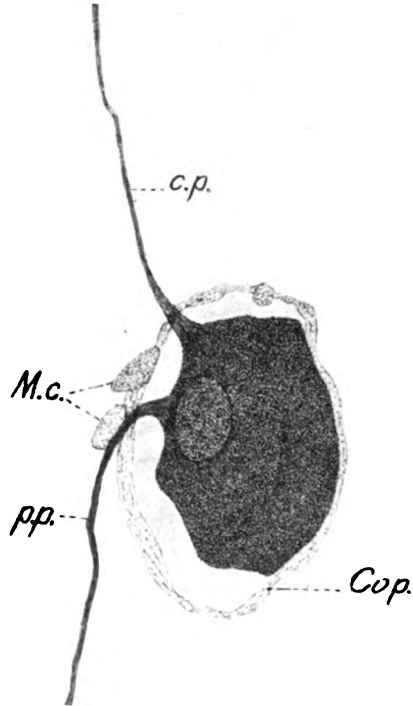


FIG. 12.

FIG. 12. Intermediate stage from the same ganglion as Fig. 11. $\times 530$.

size, shape and position. It is rounded or oval in shape and, as is seen from the figures, rarely centrally located in the cell. The nucleus contains at least one large deeply staining nucleolus (nucl). Quite regular is the presence of two such elements. Figs. 1, 3, 5 and 7.

The Ganglia of the Tenth Cranial Nerve of Squalus acanthias

Embryos. Of the ganglia composing the vagus group, those supplying the gills resemble very closely the ganglion of the ninth nerve.

There was observed in sections a series from bipolar to unipolar cells similar to that described for the ninth. Figs. 11, 12 and 13. In Fig. 13 the processes arise from a common prolongation of the cell body.

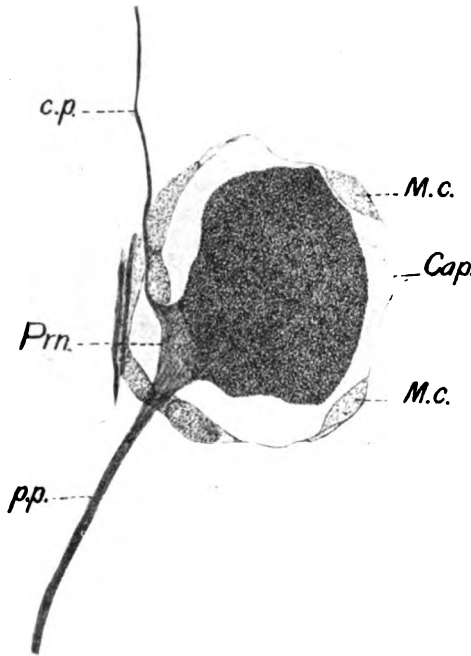


FIG. 13. Intermediate stage showing common origin of the processes Pr. n. From the same ganglion as Fig. 11. $\times 530$.

Figs. 11, 12 and 13 are all from the same ganglion. In all three cells the peripheral process, p. p., is considerably thicker than the central process, c. p., and this occurrence is constant for the ganglion.

Sling arrangements, similar to those on cells of the ninth, were rarely seen, and the accessory processes of the adult was lacking.

The other ganglia of the vagus, so far as observations go, are

simpler than the branchial and the cells have kept more completely their oppositipolar condition.

The Ganglion of the Ninth Cranial Nerve of Adult Mustelus. This adult ganglion is more complicated than those of the embryos studied. The interstitial connective tissue is more rich, and the course of the nerve-fibers is not so direct. The capsule is more highly developed, and the mantle cells are more numerous.

The predominating type of cell is bipolar, but intermediate forms are frequent. Cells around the periphery of the ganglion sending

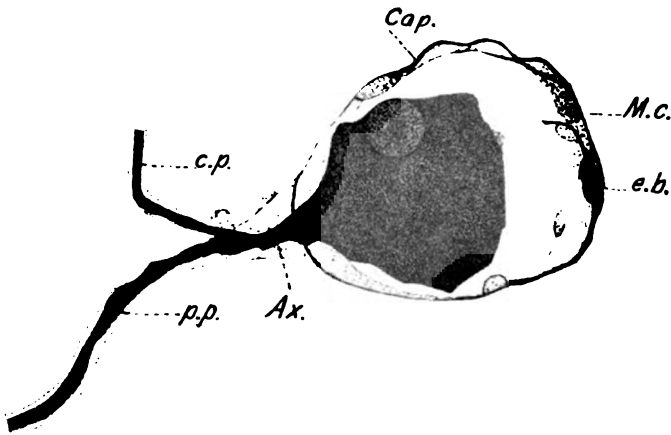


FIG. 14: Unipolar cell from the ninth ganglion of an adult *Mustelus canis*. Reduced silver. $\times 256$.

their processes toward the center are common, and in some cases they were seen to be unipolar—Fig. 14.

Many cells give off besides the regular processes a variable number of accessory branches of various sizes. (Cells A, B, C, of Fig. 15, A. c. p.)

These accessory branches range from very fine fibers ending with small bulbs, usually within the capsule, (Cell C, ac. p.) to relatively thick processes with large round or oval end-bulbs outside the capsule. (Fig. 15, L. eb, Cell B.)

Usually these extra processes are quite evenly distributed about the periphery of the cell, as in Fig. 15. In other cases a short

knob-like prolongation of the cell body gives rise to a large number of fine branches which may divide, diverge with a tortuous course, and end near the cell, usually with small thickening.

Fig. 16 shows a cell with an accessory process which divides repeatedly, each terminal fiber ending with a bulb-like enlargement. Often these accessory rami seem to anastomose with one another.

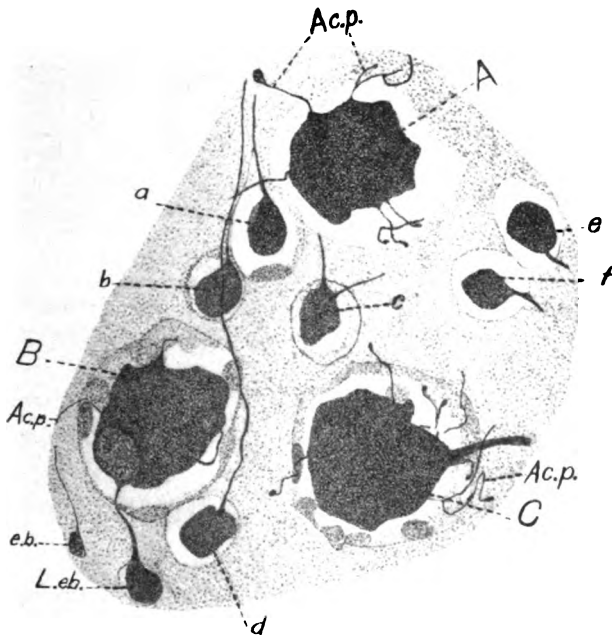


FIG. 15. Small portion of a section of the ninth ganglion of an adult *Mustelus canis*, showing accessory processes. Ac. p. and small ganglion cells, a to f. Reduced silver method. $\times 256$.

The occurrence of this condition is quite general, and in portions of the ganglion nearly every cell is affected.

Many small cells, hardly larger than the largest bulbs above described, are seen (Cells a to f., Fig. 15). These small cells are nucleated, have processes, and give a picture in miniature of the large ganglion cells. Cell c., Fig. 15, represents a geminipolar cell, indicating that in these cells also a transformation series is to be found.

The Vagus of Adult Mustelus. In the adult, as in the embryo, the branchial ganglia resemble the ninth very closely, although they are somewhat smaller and simpler perhaps in construction. Bipolar and intermediate cells were demonstrated well in silver preparations, and in addition unipolar forms in small numbers. The accessory processes observed so constantly in cells of the Ninth are present, although not seen in such numbers or in such complicated form.

The ganglia of the lateral line and visceral branches are relatively simple. Here the structure is more diffuse and the cells are not

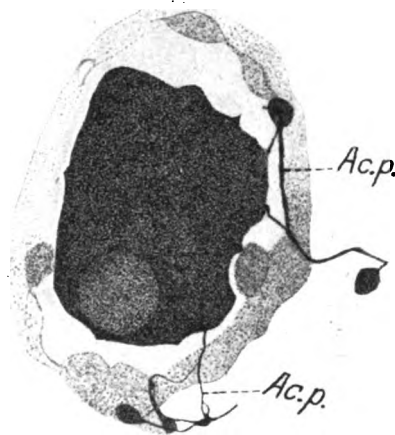


FIG. 16. Cell showing accessory processes, Ac. p. From the same ganglion as Fig. 15. $\times 530$.

crowded so closely together as in the Ninth. Consequently strictly bipolar, indeed oppositipolar cells, are the rule. These elements may be very readily isolated by teasing.

The spinal ganglia of *Squalus* embryos were studied by teasing. While much smaller, the spinal ganglion is, so far as observed, similar to the ninth cerebral ganglion in constitution, although relatively more simple.

The ganglia of the Fifth and Seventh cerebral nerves have been very briefly studied. The cells in the maxillo-mandibular and superficial ophthalmic branches were found to be exclusively oppositipolar.

The main Gasserian and Facial ganglia are very complex—perhaps the most modified of any of the cranial ganglia.

B. Observations on Mammals.

Spinal and Gasserian ganglia of the cat and dog were treated by the reduced silver nitrate method, which gave excellent results.

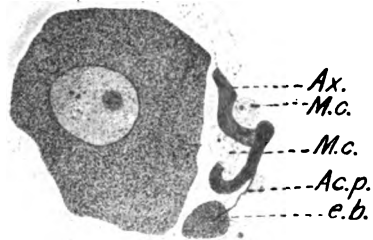


FIG. 17. Cell from the spinal ganglion of a 10 days kitten. Ac. p. accessory process. e. b., end-bulb. Silver Method. $\times 530$.

The nerve fibers stained a deep brown; the other elements of the ganglion colored less heavily.

Spinal Ganglia of the Cat. Ganglia from a ten-day kitten and the adult cat were studied. In these specimens the ganglia differ

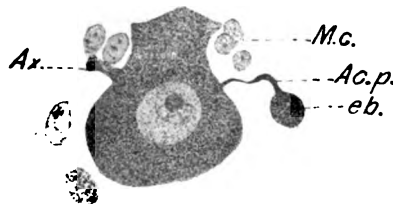


FIG. 18. Spinal ganglion cell of a 10 days kitten. Ax., axone, ac. p., accessory process. $\times 530$.

characteristically from those of the Selachians by the predominance of unipolar cells.

The cells in the ganglia of the kitten vary much in size, those in the interior of the ganglia being much smaller as a rule than those about the periphery. The round or oval mantle cells are very

numerous (Figs. 17, 19), sometimes appearing heaped up about the origin of the axone. The axone rarely leaves the cell in a direct line, but usually goes into a glomerulus which is relatively simple in the kitten. (Fig. 19.)

The nerve-fibers show a longitudinal striation due to the neuro-

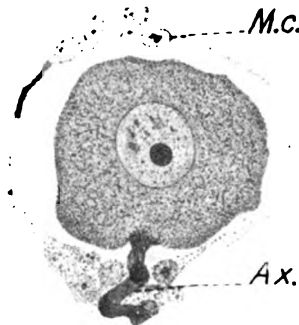


FIG. 19. Typical spinal ganglion cell of a kitten, showing a simple glomerulus of the axone (ax.). $\times 530$.

fibrillæ. The cytoplasm exhibits a complicated network, also due to neurofibrillæ. (Fig. 22.)

The process often leaves by an implantation cone from a sort of hollow in the body of the cell. Figs. 19 and 22. In some cases the process follows around the side of the cell for a short distance within

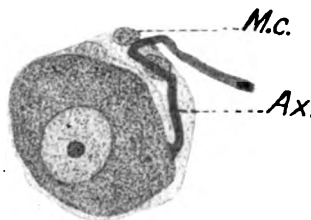


FIG. 20. Spinal ganglion cell of a kitten. $\times 530$.

the capsule, without convolutions, and then leaves the capsule in a direct line (Fig. 20), a mode of origin described by v. Lenhossék ('06).

In many sections T-formations could be seen in large numbers, one branch going centrally and one peripherally.

Processes with end bulbs, as described by Huber, Ramon y Cajal and others were present in rather limited numbers. They take the form of round or oval bulbs of various sizes, staining very evenly a brown or reddish color. They are connected with the cell or an axone by a fiber which varies greatly in thickness. Figs. 17 and 18, ac. p., e. b., illustrate such processes.

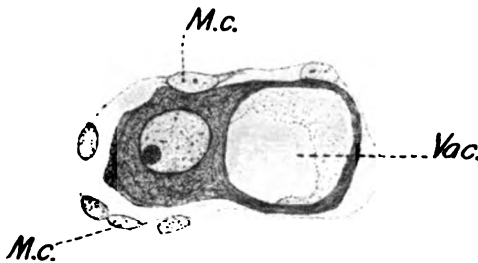


FIG. 21. Spinal ganglion cell of a kitten, showing a large vacuole or aperture (Vac.). $\times 530$.

Some processes were found which suggest the fenestrated cells of Cajal and Levi, although not exactly agreeing with his descriptions of them. Sometimes the "aperture" is very large, and bounded by a relatively thick concentrically striated band. The fibrillæ of this band extend into the cell body and appear to connect with the

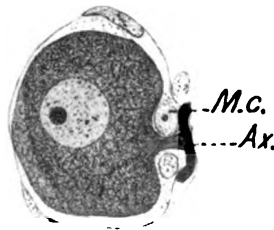


FIG. 22. Spinal ganglion cell of a kitten, showing immediate division of the axone (ax.). $\times 530$.

network in the cytoplasm. (Fig. 21.) The aperture in this cell ran through four sections of 10 microns thickness and appeared to be a closed cavity, suggesting the vacuoles described by Athias ('05). Other small vacuoles or apertures appeared in cells, but apparently not in close relation with mantle cells, as described by Ramon y Cajal and Levi.

The cells in the ganglia of the adult cat are much larger than in the kitten. The initial glomerulus is immensely complicated, and processes with end-bulbs are more frequent.

The Spinal Ganglia of the Dog. The study of the ganglia of the dog was brief, owing to the lack of time. In general appearance the sections are very similar to those of the adult cat. The glomerulus is strongly developed. V. Lenhossék ('06) found the glomerulus in the spinal ganglia of the cat and dog the most complicated of all mammals.

Fig. 23 shows a cell whose axone (ax), after a simple glomerulus, divided into two branches of unequal thickness (c. p., p. p.). A fine fiber (c. p.) arises near the axone and ends freely within the capsule.

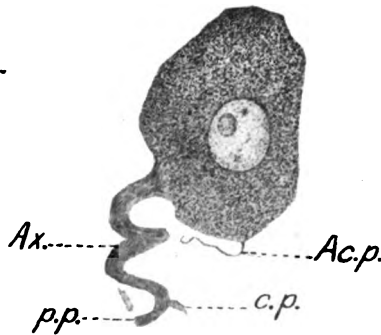


FIG. 23. Spinal ganglion cell of an adult dog. ac. p., small accessory process. $\times 530$.

The walls of the nuclei are sharply defined. The nucleolus is large, round usually, not heavily stained, and seems to be granular in composition.

In these ganglia a great many fine fibers in addition to the thick medullated processes were seen—supposedly the nerve-processes of the smaller ganglion cells. As such fibers were sometimes found to branch repeatedly, the impression that they are partly of sympathetic origin is strong, although pericellular plexuses have not been seen.

Summary. In addition to the bipolar cells which are the predominating type, certain of the ganglia of Selachians show a transformation series from bipolar cells to unipolar cells, similar in all respects

to those described by Freud, Retzius and v. Lenhossék as above noted. In the adult, besides the normal axone or axones, a characteristic appearance is the presence of a variable number of accessory branches which are of varying thickness, and terminate by end-bulbs, freely, or by anastomosis with one another or the cell body. Fine fibers, forming closed slings in the embryo of 16 cm. constitute a very simple corresponding structure. As mentioned above, Levi ('06) has described for Selachians "short thick processes which terminate after a brief course for the most part within the capsule." While Levi shows no figures, and has not described end-bulbs in this connection, the structures found in *Mustelus* probably correspond to the processes described by him. They correspond more closely, however, to his figures of homologous accessory processes in Chelonians, and are similar in nature to those found in amphibians and mammals.

Observation of mammalian ganglia confirmed, so far as the study, progressed, the accounts of Retzius, Cajal, v. Lenhossék, etc. The processes terminating in the end-bulbs offered no new features. Typical fenestration affecting the origin of the axone was not seen, and the apertures in ganglion cells resembled closed vacuoles rather than true perforations of the cell body.

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BOOK REVIEWS.

THE DEVELOPMENT OF THE CHICK. An introduction to embryology.
By **Frank R. Lillie**, Professor in the University of Chicago.
Henry Holt & Co., 1908.

Every one who has long wished for an up-to-date text book on the development in the egg of the common fowl, to replace the classic book of Foster and Balfour, and the most excellent book of Marshall, will need to judge by trial whether this is his ideal, or but the voice of one crying in the wilderness. This is a book of some four hundred and fifty pages and two hundred and fifty most excellent illustrations, six of these being full page colored plates. The illustrations are well chosen from many recent sources and very many, both surface views and sections, are original. In fact, it is this aspect of the book which is emphasized; it is no mere complication but full of the original work of the author, and the work of others has been very judiciously and fairly balanced. It may be said that the vast body of known facts on this subject has been digested by the author, digested to fit his needs; whether the process has been carried far enough to suit the tender assimilative powers of the "beginners in embryology," for whom it is said to be written, may well be doubted.

Every teacher of embryology must have the book, and the man who really wants to study the embryology of the fowl must use this as the most complete book of reference. The average beginner, however, who actually knows nothing of embryology, will scarcely have either the time or the pertinacity of purpose to get an adequate notion of the events in the egg of the fowl from such a technical treatment.

Until the second part, which treats of the organology from the fourth day on, shall have been much shortened and the first part recast in presentation, the book can scarcely be judged as a text book for beginners, though doubtless it will be an inspiration to those fortunate, good students whose teachers introduce it to them,

As the foremost book, in English, that presents the subject of the development of the fowl, as it appears *to-day*, the book of Professor Lillie deserves only praise. Throughout it is marked by conscientious matter of fact treatment and a precision that shows both in the illustrations and the text. The author's attitude is indicated by the section on the eleventh cranial nerve which is merely, "No observations on the development of this nerve in the chick are known to me." The book is restricted to the description of the visible developments of the common fowl, except for a few necessary illustrations from other birds. It is neither experimental nor comparative, barring a few very brief references to probable recapitulations. It will be understood also that there is no reference to methods and no directions for laboratory work. There is, on the other hand, an excellent bibliography of some four or five hundred recent original contributions to the subject of the embryology of the fowl.

The introductory first fifteen pages take up the subjects of the cell theory, the recapitulation theory, the physiology of development, the law of genetic restriction, the sperm and ovum and the polarity of the ovum. The book being essentially a chronicle of facts, this introduction might well be omitted.

The facts are arranged in fourteen chapters, as follows:

A brief account of the reproductive organs of the hen, the formation of the egg and the structure and chemical make up that it has when laid, makes the first chapter. As nothing is known of the fertilization, and maturation, and little enough of the cleavage, of the hen's egg; these phases are figured and described from the excellent work that has been done upon the pigeon. The second chapter devotes some thirty pages to the details of these events in the bird's egg before it is laid, including the formation of the ectoderm and entoderm. The third chapter contains a discussion of the rate of development, with a folding plate presenting the amount of development of organs in the hen's egg at different stages up to forty-one somites, at 96 hours. Here also is a brief sketch of the orientation of the embryo in the egg and its relations to the yolk sac, but the expected epitome of the entire development within the egg, as far as embryo is related to membranes, is deferred for later chapters, which must prove troublesome to the novice.

In chapter four the events from laying to the formation of the first somite are given twenty pages with excellent views of sections, as well as some surface views taken from Schauinsland and representing the blastoderm of the sparrow. The fifth chapter, though of some forty pages, includes only the events from the head fold to the period of twelve somites, thus advancing only to about the 33d hour of incubation. This indicates the detailed care with which the subject is treated, even though here as throughout, much of the space is taken up with most useful and finely executed illustrations. Chapter six runs over the events from 34 to 72 hours; but this, ending at the lapse of three times twenty-four hours, is about the only remnant of the old method of describing the chick's progress as if done by day labor. As most of the organs are laid down in this important third day, all the eighty pages of this chapter are necessary.

With the next chapter begins the second part of the book, the events of the fourth day to the time of hatching. This part is chiefly the completion or advancement of organs already begun, and such organology could, from the view point of beginners in Embryology, well be more briefly described than it is in the following two hundred and thirty pages, the more so as many students who are interested in medicine may get such information from the study of pig or other mammalian embryos.

The seventh chapter deals with the general form and the fate of the embryo with reference to the amnion, allantois and yolk sac, and much of this, as above noted, might have been acceptable earlier in the book. The beautiful colored plates of the vascular area add much to this part of the volume.

The eighth chapter deals with the nervous system, the neuroblasts, neurons, brain, cord, and origin of cranial and spinal nerves.

The ninth chapter takes up the eye and the ear where they were left in the sixth chapter and carries them to their definitive form.

The tenth chapter gives thirty pages to the alimentary tract. The eleventh some fifteen pages to the difficult problems of the body cavities and mesenteries, while the twelfth devotes thirty pages to a very good account of the later stages of the heart and the

vascular system. The remaining two describe, in each about the above number of pages, the urinogenital system and the skeleton. This presentation of the facts of the development of the sexual and the excretory organs will be most welcome to all who have not ready access to all the recent literature, and it is a good sample of the great value of the book throughout, both for the teacher and the student who is prepared to realize what has been done for him. Throughout, points that have received no attention as yet are noted, and one will not get the idea that the subject is a completed one despite the great mass of fact that has accumulated since our old texts were written. The press work and the execution of the illustrations do credit to the publishers.

The volume well represents the present status of our knowledge of the development of the fowl: a great monument of hard won facts, evidently connected with the embryology of other animals, in fact faintly illuminated still by the principle of recapitulation, but on the one hand shorn of the mysteries of the unfamiliar and on the other awaiting some future more fundamental interpretation and explanation. With the increase of accuracy and solid achievement which this volume should incite in the study of the chick, we may expect even better progress in the future and reaction for the better in the study of embryology in connection with medical schools.

Received for publication, February 19, 1909.

E. A. ANDREWS.

QUAIN'S ELEMENTS OF ANATOMY. Eleventh Edition. Vol. I. Embryology. By T. H. Bryce. Longmans, Green & Co., London and New York. 1908.

The appearance of a new edition, the eleventh, of Quain's Anatomy is a noteworthy event, since, among English text-books, this has long occupied a foremost place as an exposition of Anatomy from a scientific standpoint. The first volume of the present edition, like that of the tenth, is devoted to Embryology, a subdivision of Anatomy concerning which our knowledge has made remarkable progress since the publication of the earlier edition (1892), not only as a result of the study of greater numbers of embryos and of embryos of earlier stages of development than were formerly available, but also

in consequence of the investigation of embryos of a larger series of mammalian types having yielded results whereby the gaps in our knowledge of human development can be more accurately filled in and a significance attributed to ontogenetic phenomena which formerly were more or less unintelligible.

To cover the wider extent of territory thus made available within the compass which the conditions rendered necessary must have been no easy task, but it may be said at once that Dr. Bryce has fully maintained the high standard of excellence set by Professor Schäfer in the earlier volume. But this has been accomplished only by the extension of the present volume to 260 pages, as compared with the 169 of the tenth edition, notwithstanding that considerable space has been gained by the omission of the bibliographic lists at the close of the various sections, which were such characteristic features of the older book. Dr. Bryce has not, however, failed to supply in the foot-notes numerous references to the most recent embryological literature, those papers giving more or less extended bibliographies being especially noted. He has also added a large number of new figures, the volume containing a total of 313 as compared with the 200 of the earlier edition, and it is deserving of mention that over seventy of the figures are reproductions of original drawings by the author, many of which are of a high degree of excellence and contribute materially to the value of the book.

A detailed review of the text is hardly feasible; it can truly be said to present a very complete resumé of our knowledge of human embryology and organogeny. But the effort to condense the mass of material at the author's disposal within the proper limits is evident on every page and has occasionally led to a degree of conciseness which somewhat obscures the description; indeed, in one section, that on the skin and the cutaneous glands, condensation is carried to such an extent that no mention is made of the epitrichium, of the development of the nails, or even of that of the mammary glands. As a result of this condensation the volume is one that may be read with profit, though not altogether with ease, by one more or less familiar with the results of recent embryological investigation, but to a beginner it is to be feared that the book will prove, in parts at least, exceedingly difficult of comprehension.

For this the author is not altogether to blame, but rather the plan which endeavours to concentrate within the limits of a single text-book a presentation of our information in all its details concerning all departments of human anatomy. This is impossible without the expansion of the volume to an unreasonable size, unless much of the material be condensed to such an extent that it becomes unpalatable from its very condensation. In a text-book of Anatomy, using that term in its narrower sense, it is the histology and especially the embryology that naturally suffer in this respect, and it would be far preferable to include in such a book only so much of these subjects as is absolutely necessary to make the facts of gross structure intelligible, the student obtaining that further knowledge of histology and embryology that he ought to possess from special treatises. In other words, these two subjects, as ordinarily presented in an anatomical text-book, are treated more or less as appendages to the main topic and are, therefore, not given that space and treatment which are necessary for their successful presentation and which they deserve. They are integral parts of the anatomical discipline and also have applications apart from their importance in rendering intelligible the facts of gross anatomy. They should be taught as essential parts of the anatomical course, but they should not be presented in such a way as to give the student the impression that they are merely academic addenda to a more important and "practical" subject.

J. P. McMurrich.

Received for publication, February 12, 1909.

NOTES

ON THE PRESERVATION OF DATA USED IN BIOMETRIC INVESTIGATIONS.

At the present time there is an increase in the number of biological investigations in which long series of measurements on different characters of animals are employed.

On account of the expense, most of our journals hesitate to print the individual measurements, and it thus often happens that valuable data are either lost, or at least fail to remain accessible. In view of these facts, the Wistar Institute wishes to aid in the preservation of such data, so far as they relate to vertebrates, and to that end the following suggestions are made to authors working in this field.

1. That authors communicate with the Institute to learn whether their data fall within the scope of this plan.
2. In case they do fall within the scope of the plan, then that the data, in a complete form be sent to the Institute.
3. The Institute will copy the records on cards, and file the same as a reference archive.
4. The Institute will also make a typewritten copy of the records, to be certified by the author, and with the permission of the author, to be used by other investigators who desire to consult his data.
5. A duplicate typewritten copy will be returned to the author, together with the original manuscript.

M. J. GREENMAN, *Director*.

The Wistar Institute of Anatomy and Biology
Philadelphia, Penna.

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PROCEEDINGS OF THE ASSOCIATION OF AMERICAN ANATOMISTS.

PAPERS AND ABSTRACTS OF PAPERS READ AT THE TWENTY-FOURTH SESSION,
BALTIMORE, MD., DECEMBER 29, 30, 31, 1908.

SYMPOSIUM ON EXPERIMENTAL EMBRYOLOGY.

THE APPLICATION OF EXPERIMENT TO THE STUDY OF THE ORGANIZATION AND EARLY DIFFERENTIATION OF THE EGG.

BY

EDWIN G. CONKLIN.
Princeton University.

The central aim of all embryological study is to trace to their origins the principal differentiations of organisms; in addition the aim of experimental embryology is to be able to control these differentiations. In this study experiment and observation can never profitably be separated. More accurate observations will always be needed as a basis for more critical experiments. These two methods of study are, therefore, not antagonistic, but mutually dependent upon each other. Experimental embryology is not a wholly different study from descriptive embryology, but rather a more refined and accurate form of observation, in which emphasis is placed upon physiological processes rather than upon morphological structures. In any large view of the science the results obtained by either of these forms of study cannot be separated easily or profitably.

All sciences as they become more detailed and accurate pass from the descriptive to the experimental stage, and it cannot be otherwise with the various branches of biology. Where the materials with which a science deals are relatively simple, experiments may profitably begin at a much earlier stage than where those materials are very complex. In the case of embryology the materials are so complex that there is still a large opportunity for studies of a descriptive sort, although the experimental method will here play a larger and larger part as the science develops. But experimental studies to be of much value must always be founded upon a knowledge of the normal condition, and the more thorough this knowledge is the better.

Again to be of real value experiments must be of a detailed and individual character. Much of the early work in experimental embryology has been of a general and explorative sort; for example, eggs were treated by the thousands and the end results only in the case of a few of them noted. Now every one who has done such work knows that one of the most usual of all results is the great variation in the types and structures produced. This diversity, probably, depends upon different conditions of the organism at the time of the experiment and also upon varying actions of the experimental conditions upon the organism. Thus it has been shown that eggs are much more susceptible to injury during division stages than during resting periods, and in many cases it can be shown that the precise time and manner of modifying the normal conditions are of the greatest importance in determining the end result. All of the variables should be known for each case, and this requires individual rather than mass experiments.

These general remarks apply with especial force to the study of the organization and early differentiations of the egg. As the result of both observation and experiment we know now that eggs are not unorganized, homogeneous, isotropic, as they were once supposed to be, but that they are morphological and physiological systems, possessing certain differentiations which are correlated with corresponding differentiations of the adult. Although much valuable work has been done in this field, the results so far gained constitute

only a sort of preliminary program of the work which is yet to be done. Some of the chief points to which attention has been and must still be directed are the following:

1. *The Origin and Causes of Polarity and Bilaterality.*

It is well known that the chief axis of the ovarian egg, in many animals, coincides with the chief axis of the fertilized egg and gastrula, and that the latter, either directly or by certain bendings, becomes the chief axis of the adult animal. Is it possible to shift this axis in the egg by shifting the positions of the oöplasmic substances? Lillie (1906) and Morgan (1907) have shown that in the eggs of *Chætopterus*, *Arbacea* and *Cumingia* some of these substances may be shifted into new positions by centrifugal force without shifting this egg axis. Lillie believes that the polarity persists in the 'ground substance' which is not altered by the centrifugal force used. On the other hand, I find that this axis may be shifted in the eggs of *Cynthia* and *Crepidula* if they be centrifuged for a considerable time after maturation and before the first cleavage. Development may be normal after this shifting of the chief axis. In this case there is good reason to believe that polarity consists in the heteropolar arrangement of certain oöplasmic substances, though the results obtained by Lillie and Morgan indicate that not all of these substances are concerned.

Bilaterality appears at different times in the development of different animals; in echinoderms it is first evident in the late gastrula stage; in most annelids and mollusks at the time of the formation of the mesomere, 4d; in some annelids and mollusks at the first cleavage of the egg, in others before cleavage; in the frog and ascidian at the time of fertilization; in cephalopods and insects during the development of the oöcyte in the ovary. Is there a common cause of bilaterality, and if so what is it? According to Roux the path of the entering sperm in the egg determines the plane of the first cleavage in the case of the frog, and this usually coincides with the plane of bilateral symmetry. But it is now known that the first cleavage plane in this animal bears no constant relation to the plane of symmetry and, therefore, the path of the sperm cannot determine

the plane of bilaterality. The fact that this plane frequently coincides with the first cleavage may indicate that although the sperm may enter at any point on the egg there is a line of least resistance along one plane, the plane of future symmetry, and that, therefore, bilaterality may be present in the egg before fertilization. Among ascidians the first plane of cleavage always coincides with the plane of symmetry, and here also there is evidence that this plane is predetermined in the egg. There is convincing evidence in ascidians that one cause of bilaterality is the bilateral localization of certain egg substances. If this bilateral arrangement of substances is changed, the bilaterality of the embryo is destroyed. The bilateral arrangement of egg substances cannot be changed after the first cleavage is completed, and in general the arrangement of substance cannot be changed after cell walls have been formed. These facts lead to the conclusion that in these animals bilaterality is dependent upon a bilateral arrangement of egg substances.

2. *The Potency of Blastomeres and Oöplasmic Substances.*

It is well known that many investigators, following the lead of Driesch, have found that individual blastomeres of the early cleavage stages of many animals may give rise to entire larvæ. On the other hand, it is now known that in a large number of other animals isolated blastomeres produce only those parts of a larva which they would normally form. In the one case the blastomeres are said to be totipotent, in the other to be specified. In those forms in which partial development of isolated blastomeres takes place, the oöplasmic substances are either segregated into different blastomeres, or they are very definitely and fixedly localized in the blastomeres. This indicates that in these cases the potency of blastomeres depends upon the completeness with which the different substances are represented in them, or upon the power of localized substances to rearrange themselves into a typical whole.

Are these different oöplasmic substances specified, or is each totipotent? In certain molluscan and ascidian eggs, where these substances are very plainly visible and definitely localized, it has been shown that the development is a strict mosaic work, based upon the

localization of these substances. Here it is possible to speak of organ-forming or histogenetic substances, since each gives rise only to definite organs or tissues. In the absence of a certain substance from an egg, a corresponding part of the embryo is lacking. On the other hand, when substances have been thrown out of their normal positions by centrifugal force, they still develop, in some cases at least, into their characteristic structures. Here, then, we have both negative and positive evidence that these substances are definitely specified, that they are organ-forming. There is no doubt that different eggs differ greatly in the capacity which parts of eggs show for development. This may be due to varying degrees of differentiation or localization of these substances, or to varying powers of regulation. Further experiments must be depended upon to harmonize the conflicting results already obtained.

3. *The Mechanism of Differentiation.*

So far as the process can be directly observed, differentiation consists in the origin, localization and progressive transformation of unlike substances in cells. How these substances arise in the first place is unknown, though there is reason for believing that they are formed through the interaction of nucleus and cytoplasm; further study on this subject is much needed. The localization of these substances in the cell body is accomplished, in large part, through the achromatic portion of the mitotic figure. Lillie has shown that a limited amount of differentiation may take place in the absence of cleavage, and it has been shown repeatedly that there is no necessary relation between planes of cleavage and lines of differentiation. Nevertheless, cleavage is necessary to progressive and orderly differentiation. I have found that cell walls limit and fix the movements and localization of substances, and that the movements of substances within cells take place largely through the instrumentality of the astral systems of the mitotic figure, or of the entering spermatozoon. Differential divisions of the cell body are thus brought about, though there is no evidence that differential divisions of the nucleus ever occur, except in certain maturation divisions of the egg and sperm. Where nuclei become differentiated it is probable,

as Boveri has suggested, that it is through the influence of the surrounding cytoplasm. It is, therefore, probable that while one of the principal functions of the mitotic figure is the equal distribution of the chromosomes to the two poles, another scarcely less important function is the localization and differential distribution of the öoplasmic substances to the daughter cells.

By a series of remarkable observational and experimental researches, Boveri and Wilson have shown that individual chromosomes may possess different hereditary value. There is here open one of the most promising fields in the whole science of biology for the application of experiment to the solution of fundamental problems of cytology and development. In this connection may be mentioned also the fundamental experiments of Loeb, Garbowski, Herbst and others, on the relative influence of the egg and sperm on differentiation and inheritance.

4. *Modifiability of Organization and Differentiation.*

Finally, mention should be made of the need of experimental work to determine to what extent the organization and differentiations of the egg may be permanently modified. Hitherto, such work has been taken up only incidentally, but it is one of the greatest problems of biology, upon the solution of which the artificial production of new types must largely wait.

This brief summary of results and aims of experimental work as applied to the organization and early differentiation of the egg, is, as I indicated at the beginning, in the nature of a preliminary and very incomplete program. Experimental embryology is a new science, and the valuable work so far done is more or less isolated and disconnected. This symposium can serve no more useful purpose than to point out the lines in which work is especially needed, and to stimulate interest in the solution of the fundamental problems of development.

THE EFFECTS PRODUCED BY CENTRIFUGING EGGS BEFORE AND DURING DEVELOPMENT.

BY

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In recent years the results of experimental embryology have led to the view that however significant in the physiology of the cell, and even in heredity, the nucleus of the egg may be, the protoplasm plays also a very important role in early development. It has long been taken for granted by embryologists that the presence of such inclusions as the yolk is an important factor in determining the fate of embryonic cells. The presence of pigment in certain parts of the egg, as in the red ring in *Toxopneustes*, and the yellow band in *Cynthia*, has made it possible to follow movements that take place in the cytoplasm, and these movements are definitely associated with the formation of organs. The pigment allows us to follow certain movements that might otherwise escape our attention. The movements show, at least, that there are accumulations of materials in certain regions of the egg preparatory to the development of organs in those regions. How far this accumulation means that previously existing *differential* materials are segregated, and how far it means that differences are arising in the egg materials, is the point that I shall here consider.

We owe to E. P. Lyon the introduction of a new method into embryology by means of which we shift at will many of the substances contained in the egg, and in consequence analyze further their function in embryonic development. The experiments have already yielded most important results, and I venture to prophesy that we are only at the beginning of further discoveries.

If the visible substances of the protoplasm—inclusions I may call them—act as the initiators of later differentiation, we might expect, if their distribution is altered, to find an extremely abnormal product.

If, on the other hand, the inclusions are not organ-forming materials, we should expect to find normal development after their displacement. These alternatives put in sharp contrast the extremes of expectation. As I shall point out later, they do not exclude other less radical interpretations.

If the egg, either before or after fertilization, is placed in the centrifuge and rotated at the rate of about 8000 revolutions per minute, a stratification of the materials takes place. The heaviest materials are driven to one end, and the lightest to the other. Even the nucleus will be carried through the protoplasm and pass to one pole of the egg. In most cases, it appears, that the eggs fall without regard to their polarity, hence the nucleus and the inclusions of the protoplasm may come to occupy positions with respect to the unmoved parts of the protoplasm that are entirely different from their normal relations.

If the egg is rotated more slowly but for a longer time, the same result is accomplished, and this method has in some cases a decided advantage. For instance, the egg immediately after its fertilization may be placed in the machine and kept rotating during its early development. In this way we can insure against the possible redistribution of the stratified materials.

I need not point out to you the wonderful delicacy of the centrifugal force, by means of which we can shift at will the contents of the egg without injuring the egg, as the sequel will show. The method, as I have said, opens a new era in experimental cytology.

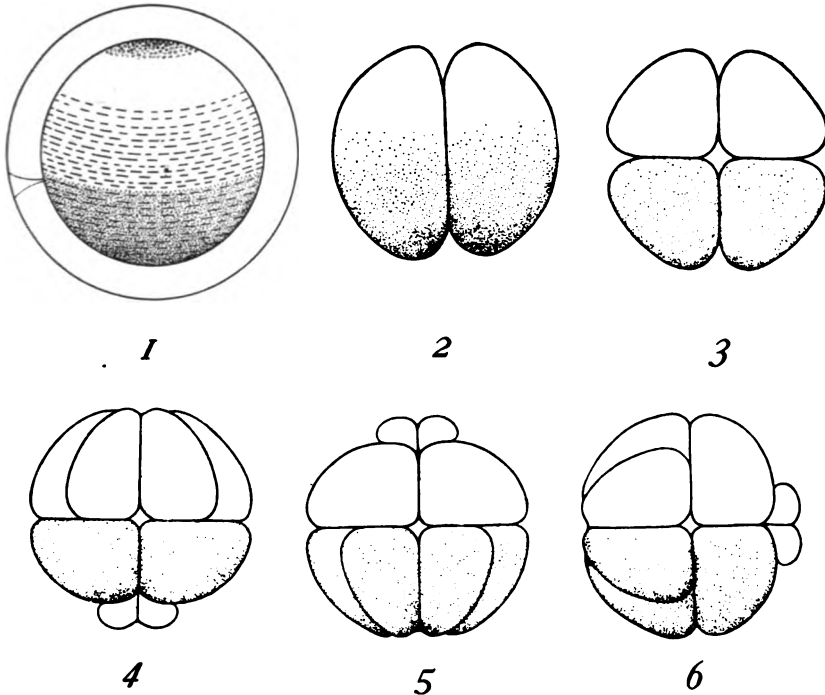
I wish now to bring before you some of the results already obtained, and, if I speak more especially of those forms that I have studied, it is because I have here a knowledge of the facts at first hand.

The egg of the sea urchin *Arbacia* has given, I think, the most definite, positive results. The egg after centrifuging is shown in the first figures of the diagram (Fig. 1). Four distinct zones are present—a light whitish cap of oily matter, a middle perfectly clear protoplasm, a band or segment of yolk and a red pigmented base. The nucleus lies just beneath the oil cap.

The normal egg has a definite polarity which, as Boveri showed,

stands in relation to the point of fixation of the egg to the ovarian wall. This point is marked later by the attachment funnel that runs through the jelly-like outer membrane. It serves, therefore, to determine the original axis of the egg.

The centrifuged eggs show that the stratification stands in no constant relation to the egg axis (see first figure). In other words, the egg is centrifuged as it happens to fall in the tube.



The first cleavage begins, almost invariably, at the white cap - where the nucleus lies and cuts through the egg, dividing the stratified materials at right angles (Fig. 2). The second plane is at right angles to the first (Fig. 3), lying near the line of separation of yolk and clear zone, and the third at right angles to both (not shown in figures). The fourth cleavage is a differential cleavage (Figs. 4, 5, 6). Four micromeres appear at one pole; the cells of the opposite hemisphere divide equally. This cleavage is a critical one, for the

micromes show in the normal egg where the digestive tract will develop. The micromeres become the mesenchyme.

If the position of the micromeres in the centrifuged egg is followed, it will be found that in these eggs also the archenteron develops at the micromere pole. Furthermore it has been determined that the micromeres do not develop with respect to the secondary induced axis, but lie opposite to the attachment funnel. In other words, while the first three cleavages come in with respect to the stratification, the fourth or differential cleavage comes in with respect to the original egg-axis (Figs. 4, 5, 6).

Around the micromere pole as a center the development of the embryo takes place. A perfectly normal pluteus is formed. In some of these plutei the red pigment is contained in one region; in others, in other regions. Similarly for the yolk.

The results prove triumphantly that the materials that centrifuge in the egg of the sea urchin are not organ-forming.

Let us turn now to another egg, that of the mollusc, *Cumingia*. The former egg, that of the sea urchin, has *at first* a less determinative type than the mollusc; hence the importance of taking up a different form.

Three substances appear after centrifuging, the yolk at one pole, the pigment at the other, and a clear zone between.

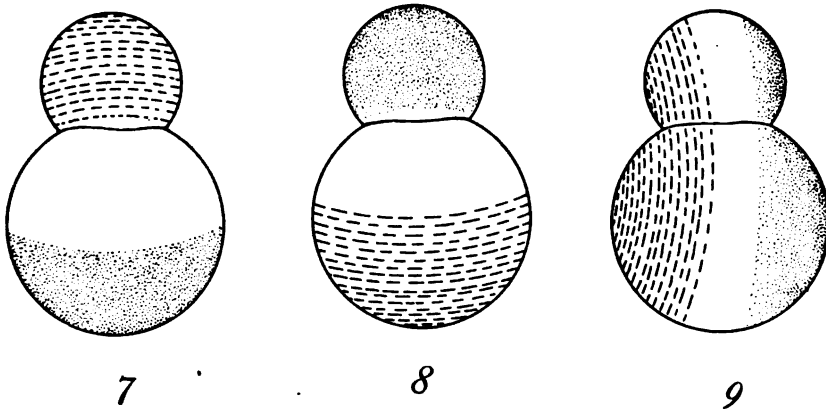
The first cleavage is shown in the following figures. (Figs. 7, 8, 9.) It will be noted that the first cleavage plane pays not the least attention to the distribution of the materials. All of the yolk may be in the small cell, or the small cell may contain all of the pigment. This difference of results may be due to the fact that in the sea urchin the nucleus is driven to one pole, while in the mollusc's egg the polar spindle has developed when the egg is laid. The centrifuge is unable to change the position of the spindle, although it can change readily the resulting nucleus. I suspect, however, that the difference is more profound and that in *Cumingia* the first cleavage plane is a differential one, like the fourth plane in *Arbacia*. But note, it is differential not with respect to the inclusions of the egg but with respect to the polarity of the egg.

For some reason unknown to me the eggs of *Cumingia* do not

develop well in dishes as far as the bivalve stage, despite the fact that the cleavage and early development is quite normal. I have had great difficulty in obtaining embryos, and this applies equally to normal and to centrifuged eggs. Whenever I have obtained later stages in the one, however, I have also obtained them in the other, so that after a prolonged study I can now state that the centrifuged eggs of *Cumingia* are also capable of producing normal embryos.

These results show, I think, that the visible material of these eggs, such as yolk, oil, pigment and perhaps other granules, are not necessarily organ-forming or even organ-determining.

I should, however, give you a wrong impression if I left the



matter here. In other eggs it has been shown that the centrifuge acts injuriously. In the fertilized frog's egg, for example, I found that if centrifuging were carried on for too long a time, abnormal development takes place. Just what happens is not clear. That the disturbance of the materials may interfere with normal movements in the protoplasm essential for development is quite possible. I could give examples of such conditions. It may also be possible that some of the inclusions are necessary for the cells, as food, for instance. Their removal from the cells might, therefore, act injuriously. It seems almost a foregone conclusion that even if the young stages of centrifuged eggs are normal, later stages may become abnormal or fail to be attained, for with all the yolk in the ectoderm

and none in the digestive tract we should expect abnormal nutrition. Again the nucleus may be carried so far from a position essential to it when the differential cleavage occurs that it fails to reach its proper location at the proper time. I could give evidence to show that displaced nuclei do endeavor to reach the proper place for a differential cleavage.

All of these conditions, and probably more, must ultimately receive careful attention. Failure of a centrifuged egg to develop normally may be owing to any one of them, but the positive results show, I think, with all clearness that the visible inclusions in the cytoplasm of the kinds here referred to are not organ-forming substances; their role in development is of secondary importance. Behind them lies an organization that is the chief director of the series of events that characterize development. The visible materials of the egg follow and do not lead in the development.

Both in the case of the sea urchin and of the mollusc I have spoken of certain cleavages being *differential*. You may fairly ask for an explanation of my meaning; whether nuclear or cytoplasmic; and if the latter how differential if not a separation of different materials.

Here it seems to me is the really vital question that remains to be settled by further study. The evidence we have does not justify us, I think, in supposing such a cleavage to be the result of special nuclear interference; nor do I think it due to the segregation of already existing preformed materials. I am inclined to adopt the view that a differential cleavage is one in which a physical condition is reached that marks a further step in development. The division is differential not in the sense of separating things previously mixed, but it is a creative phase by which something new is produced by the bioplasm. It occurs at the first division in the mollusc, but at the fourth in the sea urchin. The same kind of change may even go on before any division has occurred. The results here described for the egg of two species does not, of course, preclude the possibility that in other eggs a change similar to that which occurs at a differential cleavage may occur in the egg prior even to the first cleavage and after the ripening period. The results that Conklin has obtained

in the egg of Ascidian, *Cynthia*, fall under this class. If, as I suppose, the early differentiation of different regions of the bioplasm is a physical fact of the living substance, such a change might readily take place before the first cleavage. The results of isolating blastomeres show definitely that removal of parts of the egg, after a differential change has taken place, seriously affects in many cases the subsequent development, and if the centrifuge is capable of displacing such differential areas or of interfering with their formation, or of making difficult the subsequent development by filling them with indifferent materials, abnormalities may take place.

It has been shown, especially by Conklin, that extensive movements of materials take place before the first cleavage and also in subsequent cleavages. Such movements seem to be connected with the formation of organ-forming regions. Whether such movements mean that differential materials already developed are moved to their definitive locations, or whether the movements are themselves the expression of differential changes taking place, or whether such movements are simply the outcome of karyokinetic movements, we do not know positively.

Perhaps I should add, in order to prevent misunderstanding, that, although I dispute the view that the visible substances in the sea urchin's egg acted upon by the centrifuge are organ-forming, I hold that development is the outcome of physical changes in the egg. The materials that characterize the different structures and organs of the body are the end product of changes that the egg-substance undergoes in its development. Differentiation is a product of the activity of the egg, the egg itself before cleavage is not the sum total of those materials that characterize the organs of the body.

VARIATIONS IN SUSCEPTIBILITY OF AMPHIBIAN OVA TO THE X-RAYS AT DIFFERENT STAGES OF DEVELOPMENT.

BY

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In experiments with living organisms, it is necessary to take into account variations in internal conditions and in the environment, as well as the nature of the specific influence brought to bear upon the organisms. Thus toad or frog ova are much more readily injured when over-ripe at the time of fertilization than when fertilized at the normal period, and, as a rule, are hardier in moderately cool weather than in hot. Owing to variable factors of this kind, the results of exposure of sex-cells to x-rays of a given intensity for a given period of time are not uniform in detail in a series of experiments, although the general results are fairly uniform. There is, moreover, great individual variability in susceptibility in any given lot of sex-cells, so that the percentage of organisms affected as well as the extent of the abnormalities of development of the organisms affected must be taken into account in estimating the effects of the rays.

Exposure of females, in which the eggs are still ovarian, will prevent the ripening of the eggs. The eggs remain indefinitely in the ovaries and are not capable of artificial fertilization. Exposure of the sperm or of ripe ova to intense x-rays for a considerable period of time seems not markedly to affect the power of fertilization. The earlier stages of cleavage in fertilized ova, when one or both sex-cells have previously been exposed, are apparently nearly normal, but if the exposure has been sufficiently severe, abnormality in development of a considerable percentage of eggs appears at the time of gastrulation. Gastrulation may be markedly interfered with, being either interrupted at an early period or so modified that spina-bifida or similar abnormalities result. If the effect is less

severe, the abnormalities begin to appear at the time of the differentiation of the alimentary canal and the neural tube, either or both of which may be abnormally formed. When the action of the rays is less marked, the abnormalities appear in one or more parts of the organism at a still later period. The vascular system may fail to develop, or various abnormalities may appear in any of the newly-forming organs. When the effects are slight, the deformities may not appear until the larvæ are well advanced and then merely in a small percentage of the larvæ. Thus, for instance, a hind leg may fail to develop in some individuals.

Exposure of a fertile female toad for one hour and the subsequent fertilization of the eggs with normal sperm caused in my experiments most of the eggs to develop marked abnormalities, many of them of the spina-bifida type. Nevertheless, a few individuals developed into normal tadpoles. When a female frog was exposed for an hour and fifteen minutes, and the eggs were subsequently fertilized, at the end of seven days all the ova were abnormal in form. Exposure of spermatozoa for a corresponding period leads to essentially similar results. In one experiment with toads in which the sperm was exposed for one hour, about 88 per cent of normal ova fertilized by the sperm developed into tadpoles abnormal in form, while, when the sperm was exposed one hour and a quarter, all the ova fertilized, in one instance over 250 specimens, were abnormal at the end of five days. In one experiment in which toad sperm was exposed for one-half hour to the x-rays, only 1.2 per cent of the eggs developed normally, but in other instances the percentage was greater than this.

Several experiments were made to test the action of the x-rays on fertilized ova at different stages of development. In one series of experiments, from a single female toad eggs were removed, fertilized with fresh sperm and then exposed at successive intervals for one-half hour to the x-rays. Of those exposed during the first half hour after fertilization, 22.3 per cent were undergoing apparently normal development at the end of two weeks. During this period of exposure the second polar body is given off. Of those exposed during the second half hour, 17.5 per cent were apparently normal

in development at the end of two weeks. Of those exposed during the third half hour, 68 per cent were normal at the end of two weeks. During this period of exposure the male and female pronuclei were approaching one another. Of those exposed during the fourth half hour, but 4.8 per cent were normal in appearance at the end of two weeks. None of those exposed for half an hour during the subsequent stages of cleavage up to the 64th to 128th cell stage developed normally. In later cleavage stages, however, exposure had a less marked effect. Thus of eggs exposed thirteen hours after fertilization for half an hour, at this time in a state of advanced cleavage, 64.2 per cent were apparently normal in development at the end of two weeks. Eggs exposed between thirteen and twenty-four hours after fertilization, for half an hour at a time, varied in the percentage of those developing normally from 60 to 80 per cent. Eggs exposed for one-half hour periods after the first twenty-five hours, that is after the blastopore was closed, practically all developed normally. Exposure of the eggs after closure of the blastopore and of young larvæ for several hours to the x-rays failed to produce any noticeable abnormalities of form.

In other series of experiments a considerably smaller percentage than in the series cited of eggs exposed for one-half hour during the first hour and a half after fertilization developed normally, but otherwise the results corresponded with those given.

These experiments show conclusively that both the male and the female sex-cells may be so altered by the x-rays as to give rise to the formation of monstrous forms. The susceptibility of the male and female sex-cells is approximately equal, although the abnormalities appear earlier in development and are greater when the ova are exposed. After fertilization until cleavage begins, the ova at first appear to be no more susceptible than the sex-cells before fertilization. During the earlier stages of cleavage the susceptibility of the eggs to the x-rays is markedly increased, but during the later stages of cleavage before closure of the blastopore the susceptibility of the eggs becomes much less, and after the blastopore is closed the power of the x-rays to influence development becomes strikingly reduced. The period of greatest susceptibility is the period during which there is the most rapid production of nuclear material.

THE ARTIFICIAL PRODUCTION OF ONE-EYED MONSTERS AND OTHER DEFECTS, WHICH OCCUR IN NATURE, BY THE USE OF CHEMICALS.

BY

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The differences which exist between two animal species are doubtless in some way associated with the different chemical compositions of the eggs from which the species arise. Whenever the chemical complex of an egg is so disturbed that it cannot be readjusted, the animal which arises is abnormal. Theoretically the abnormality should be definitely the same under identical changes of composition. It might be expected that each chemical change induced within a given variety of egg would result in a characteristic embryo. However, development is so difficult to analyze in detail, and the egg composition is so complex that until now we have only succeeded in recognizing a few specific abnormalities as results of definite chemical actions. Among vertebrate embryos only one monstrosity, known to occur in nature, has been consistently produced by the use of a given chemical substance. Other known defects, such as spina-bifida, cauda-bifida, etc., often occur in embryos resulting from eggs treated with metallic salts, but the occurrence of these abnormalities is irregular and uncertain so that the experimenter can never predict with confidence his result.

On the other hand, in the action of the metallic ion Mg on the eggs of the fish, *Fundulus heteroclitus*, the case is very different. Here the experimenter may predict with certainty that a given strength solution of $MgCl_2$ or $Mg(NO_3)_2$ will cause a considerable percentage of embryos to present the cyclopean defect. The one-eyed monsters occur in 50 per cent of the eggs when a favorable strength solution is employed. All of the eggs do not give rise to

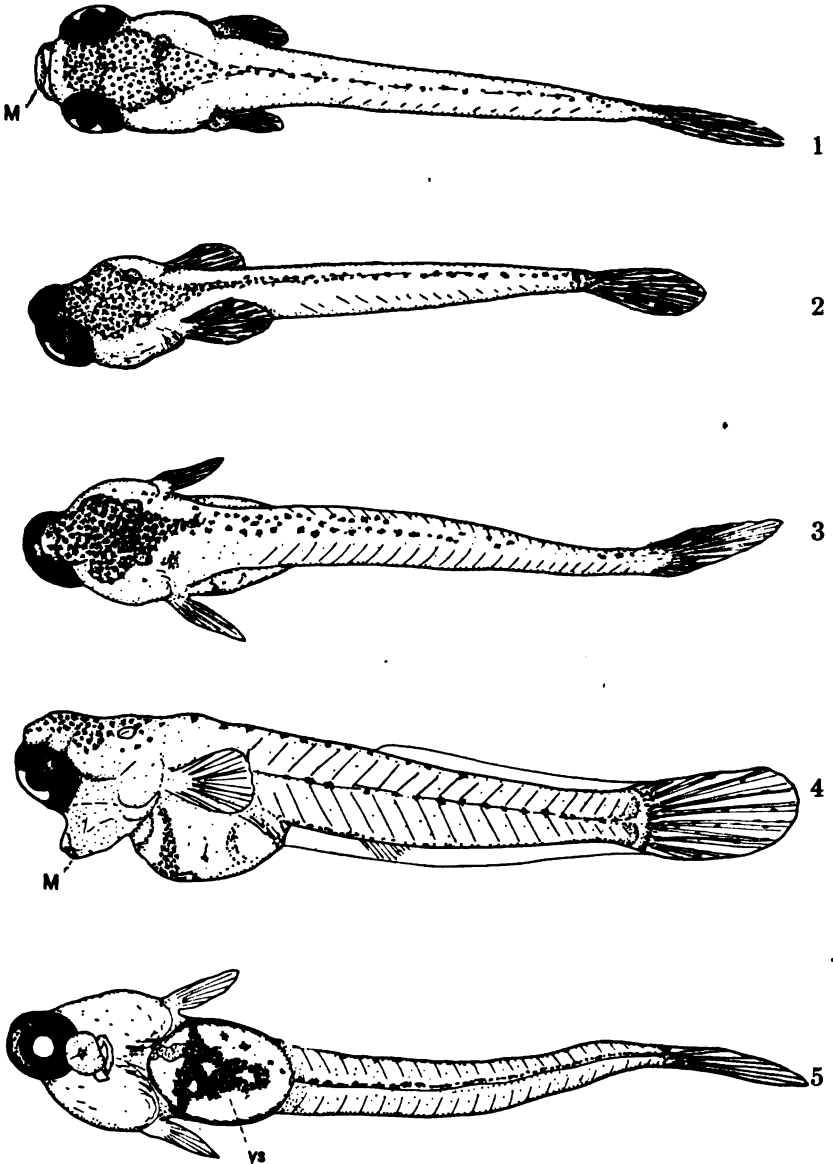


FIG. 1.—A normal free-swimming *Fundulus* embryo.

FIG. 2.—An individual from the magnesium solutions with its two eyes approximated.

FIGS. 3, 4 and 5.—Three views of a typical cyclopean monster from the magnesium solutions. The single eye is antero-medial in position and causes the mouth to project ventrally as a proboscis-like organ. M, mouth; ys, yolk-sac.

cyclopean individuals merely because they are not all affected by the same delicate point of concentration in the solutions. The more hardy eggs would require stronger solutions to produce a response while weak eggs often die in a strength of MgCl_2 which causes cyclopia in eggs of the average powers of resistance.

The cyclopean fish embryos are in all respects exactly comparable to the human cyclops. One eye exists in the middle of the face and the nasal pits are often represented by a single or double pit in front of the eye. The eye conditions show all steps in a series beginning with two eyes unusually close together, two approximated eyes, a double eye with two lenses, two pupils, etc., a laterally broad eye with a double retinal arrangement, and a single lens and pupil and a typically single eye showing no indications of its double nature. The latter condition may be termed typical or perfect cyclopia, from this we pass to extreme cyclopean eyes which are unusually small, sometimes deeply buried in the head, others with small optic cups and illfitting lenses which protrude beyond the eye, and, finally, all retinal or optic cup portions of the eye may be absent, with independent lenses present, or both optic cup and lens may fail to form and eyeless creatures result. Many illustrations of all these stages have been found and studied among almost three hundred cyclopean fish, which were produced during the past summer.

Some of the embryos present perfectly normal bilateral brains and show no abnormality other than the cyclopean eye and characteristic proboscis-like mouth. Many of the monsters hatched in the usual manner and swam normally, giving every evidence of being able to see perfectly by means of the single anterior eye. The bodies of others were slightly twisted or bent after hatching and these swam rather abnormally, although their vision seemed unimpaired. Figs. 1 to 5 represent the free swimming fish, Fig. 1 shows a normal individual, below this is a cyclopean monster with its eyes approximated and, finally, a dorsal, lateral and ventral view of a typical one-eyed cyclops is shown by Figs. 3, 4 and 5.

The development of the cyclopean eye in human monsters has been difficult to interpret on account of the scarcity of material and want of early stages in the defect. Such abnormalities are not easy to

interpret from later stages. In the summer of 1906, when these monstrous fish were first produced, I studied only later stages and on finding all degrees of doubleness in the eyes concluded that the cyclopean condition resulted from a more or less intimate fusion of the two eye components after they had arisen from the brain. This position has been held by other workers both before and since my study. A more careful investigation, however, of the earliest stages of cyclopia in the living eggs and in sections shows that the final condition of the eye is foreshadowed in the first appearance of the optic anlage from the brain. The early eye is either perfectly single or double from the start, and the union of the two components does not become more intimate during development, even though the eye may develop partially within the brain itself.

An incomplete diprosopus monster with three eyes and one additional lens extends the series of eye monstrosities in the fish to the opposite side of the usual two-eyed condition. This monster has a pair of eyes arising from one head component, and a single eye from the outer side of the other head, while on the inner side of this head there is entire absence of an optic cup, although a perfectly differentiated lens exists.

A new type of eye monstrosity occurred with regularity in the Mg solutions. These individuals had one perfect eye of the normal pair in its usual position, while the other eye was either abnormally small or represented by a solid mass closely applied to the brain, or still in other cases all evidence of the optic cup parts was absent and a free lens occurred on that side, or, finally, both optic cup and lens were wanting on one side of the head.

Again as in the cyclopean defect, the embryo will hatch with its eyes in dissimilar conditions comparable to the state of things shown when they first become differentiated from the brain. The difference in size of the two eyes is not overcome during development, and, on the other hand, there is no further degeneration of the small eye. I have termed these individuals "*Monstrum Monophthalmicum Asymmetricum*," the monster with one asymmetrical eye, as distinguished from the cyclopean monster with the single eye in the middle of its face. These unequal eyes may possibly result from an

unequal allotment of eye material to one side or the other, or the entire anlage might by chance occur on one side. In a sense this would be lateral cyclopia.

A point of particular interest to experimental anatomists is the frequent independent occurrence of crystalline lenses in these embryos. Experiments on frog embryos in which the optic cup was cut away or transplanted have seemed to show that the lens arises from the ectoderm as a result of a stimulus received from the optic cup; and further it has been shown that in some amphibians the lens is incapable of self-differentiation after it has arisen unless the optic cup stimulus continues. The cyclops fish is entirely out of accord with such conclusions. Here we find lenses arising from the ectoderm in embryos which lack optic cups entirely, or in others where the optic cups are far removed from direct contact with the lens. The lens, then, arises independently of the optic cup stimulus, and it is also evident that after its formation it continues to self-differentiate and gives rise to lens fibres and, finally, results in a clear transparent body perfectly invisible in the living embryo but clearly demonstrated in sections.

Thus it is shown that by changing the chemical environment of an egg the experimenter may produce conditions similar to those which have been tested by mechanical operations. He has the advantage of knowing that no tissues have been cut away or mechanically destroyed.

We may now ask what causes these one-eyed monsters? Many theories have been advanced to account for cyclopia. The French observer Dareste attributed the condition to a closed brain or the failure of the anterior vesicle to develop, thus allowing the parties rétiniennes to come off in approximation. This idea is opposed by the fact that Spemann has found cyclopia to occur in Triton embryos while the brain tube was hollow. Peculiarly enough I find that the optic-outpushings in *Fundulus* are normally given off while the brain is yet solid. Thus according to Dareste all of these fish would be cyclopean in nature.

The single brain condition or the failure of the fore-brain to develop is not a definite cause of cyclopia since such conditions are

not always accompanied by the defect, and, on the other hand, many of the cyclopean fish have perfectly developed bilaterally lobed fore-brains.

Spemann thinks that in his Triton cyclops the anlagen of certain tissues are lost, consequently these parts never begin development, and organs situated lateral to them develop in contact from the start. The cutting experiments in which tissue between the eyes is destroyed seems to support Spemann's view.

This explanation, however, does not seem to fit all cases. In the "Magnesium Embryos" why should tissue between the eyes fail to form and no other tissues? why are the nasal pits sometimes united and sometimes separate in cyclops? A close microscopical examination of the brain floor in cyclopean and two-eyed embryos shows no absence of recognizable parts in the former. The monstra monophthalmica asymmetrica are to be explained. Are these due to the absence of the early anlage of one eye?

The various degrees of cyclopia, the imperfect formation or absence of one eye and entire absence of eyes are conditions common to the magnesium solutions and very rare or never occurring in other solutions or in the hundreds of eggs observed developing in seawater. These conditions, probably, have a common cause, and I suggest hypothetically that this cause is an inhibitory or anæsthetic effect of the magnesium on the process of out-pushing and separation of the optic vesicles. Magnesium is known to exert a decidedly anæsthetic effect upon both vertebrate and invertebrate animals and is an inhibitor of muscular activity. It might possibly inhibit the giving off of the optic vesicles or prevent their early separation in the brain, so that both might come off together as in cyclopia. It is, of course, necessary to find a definite point in the strength of the solutions in order to obtain the proper amount of inhibition.

Finally, these experiments show that an egg which had begun development normally and which would have given rise to a two-eyed individual may, at the will of the experimenter, be caused to produce a cyclops monster. Thus the germinal theories of cyclopia are shown to be unnecessary as explanations of its cause; since here

it is undoubtedly due to the influence of external conditions acting upon the egg substance.

The suggestion is evident, though highly speculative, that cyclopia in man and other mammals might be due to a similar chemical cause, an excess of magnesium salts in either the mother's blood or the amniotic fluid surrounding the developing embryo.

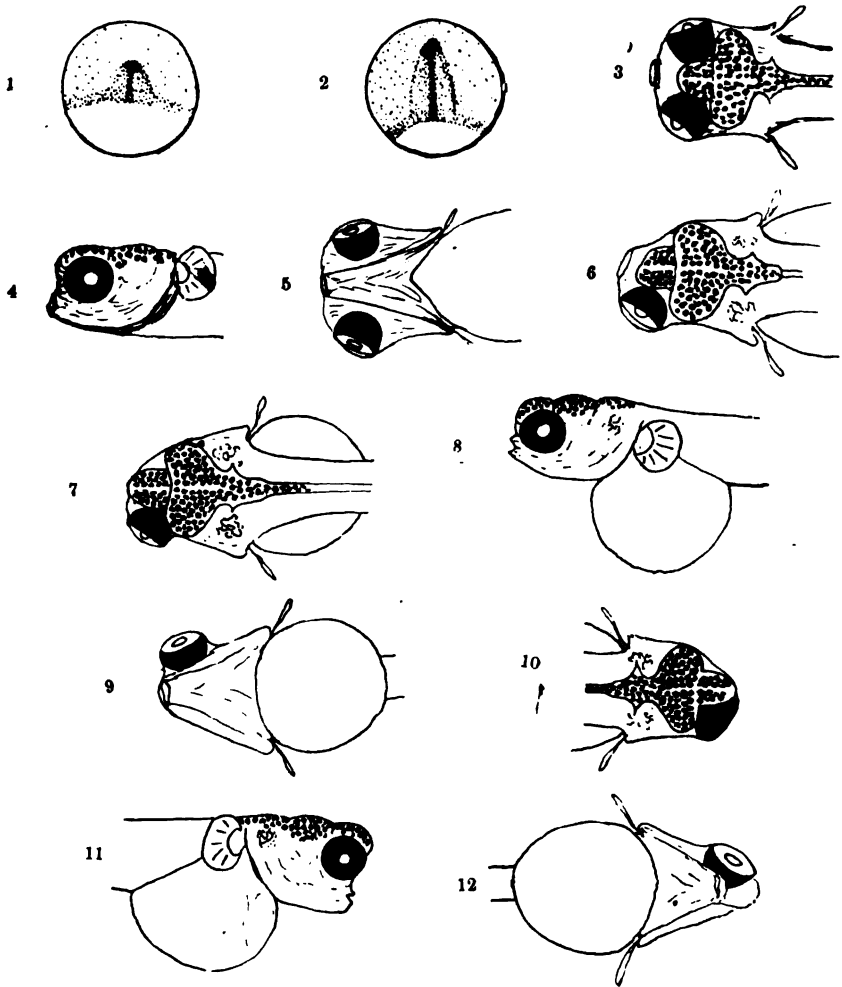
THE EXPERIMENTAL PRODUCTION OF CYCLOPIA IN THE FISH EMBRYO (FUNDULUS HETEROCLITUS).

BY

WARREN H. LEWIS.
Johns Hopkins University.

In a series of experiments on localization and regeneration in the fish embryo it was noted that defects, made in the anterior end of the embryonic shield, often gave rise to cyclopean forms. With the renewed interest in the subject since the publication of the papers by Spemann and Stockard, it seems desirable to indicate this mechanical method by which these forms were produced and to enter somewhat upon the bearing they may have upon the theories of the origin of Cyclopia. Physicians have been interested in Cyclopean monsters for centuries and many theories concerning their origin have been advanced. Two groups of theories are to be recognized, the germinal and the environmental. Concerning the germinal origin there is no direct or indirect proof such as might be obtained were cyclopean monsters viable and capable of sexual maturity and subsequent reproduction with the possibility of transmitting to their offspring the same peculiarity, through peculiarities in the germplasm. The very fact that this chance of transmission is eliminated would speak against the germinal origin. There is considerable evidence in favor of the second view, that Cyclopia are due to some modification of the embryo during the early stages of development. The experiments of Spemann and Stockard and likewise of the ones recorded below seem to support this view. Spemann's¹ experiments consisted in constricting the eggs of triton during the two cell or later stages by a fine thread about the circumference of the first cleavage plane. Double headed monsters, exhibiting varying degrees of fusion of

¹Ueber experimentell erzeugte Doppelbildungen mit cyclopischem Defekt. Zool. Jahrbuch., Supp. VII, 1904.



FIGS. 1, 2.—Showing embryonic shield at operation stages. The black area shows usual amount of tissue lost by the operation.

FIGS. 3, 4, 5.—Dorsal, lateral and ventral views of normal head shortly after hatching.

FIG. 6.—Experiment ha_4 . Operation on stage 2 (see Fig. 2).

FIGS. 7, 8, 9.—Experiment ha_{11} . Operation on stage 2. Right eye completely absent.

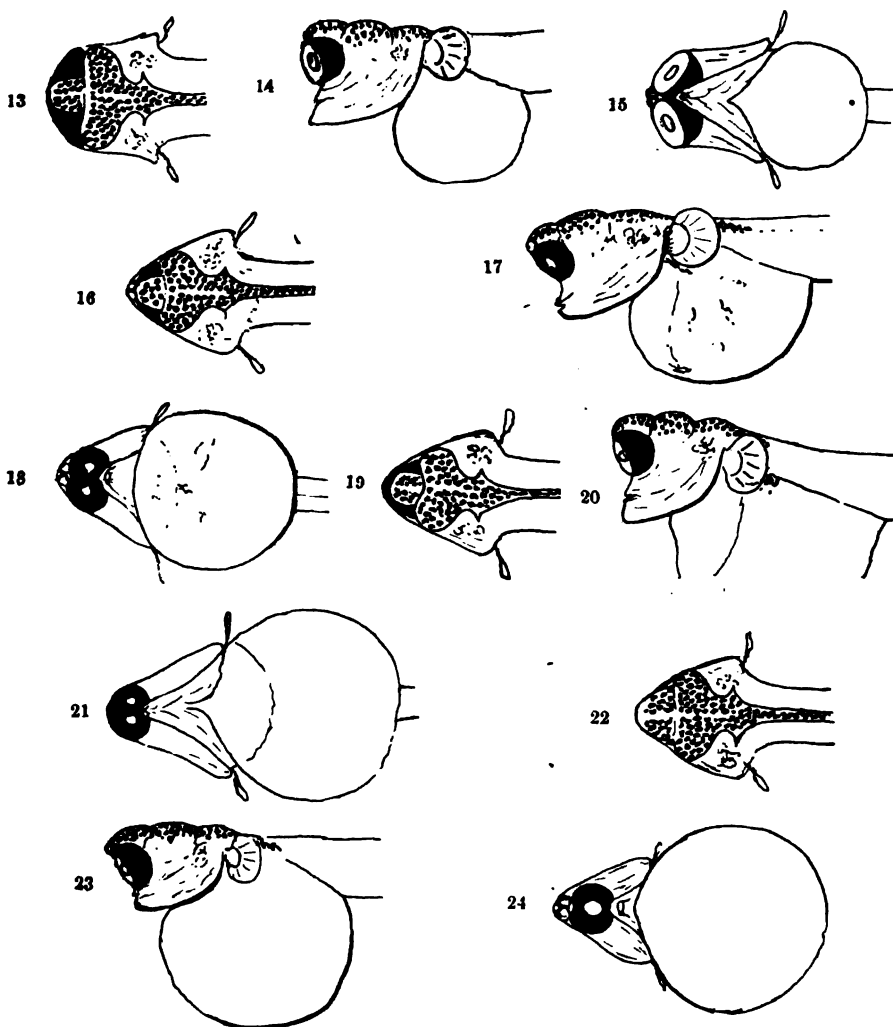
FIGS. 10, 11, 12.—Experiment ha_1 . Operation on stage 2. Left eye entirely absent.

two or more eyes were often produced. This fusion of the eyes was probably primary before the eye rudiments were recognizable. In Stockard's² experiments on fish embryos (*Fundulus heteroclitus*), the eggs shortly after fertilization were placed in sea water solution of magnesium chloride with resulting production of the cyclopean condition in a large percentage of the eggs. The cyclopean condition is also primary in these experiments, "the earliest indication of an eye is just as truly cyclopean as it will be later," Stockard.³ Neither Spemann's nor Stockard's cyclopean monsters can be looked upon as germinal in origin but are truly due to environmental conditions. The additional data from the following experiments extends the possibility of cyclopean monsters depending upon abnormal influences exerted during early embryonic development. These experiments were done at the Marine Biological Laboratory, Woods Hole, Mass., and a few of the typical ones are given below. Such forms were easily reproduced during two succeeding seasons.

The experiments were made on the eggs of *Fundulus heteroclitus* during the embryonic shield stage. The egg was held with a small pair of forceps and a very fine needle was thrust through the egg membrane into the anterior end of the shield; as the needle was withdrawn slight pressure on the forceps caused some of the material of the embryonic shield in the region of the needle prick to be extruded. As the experiments were done under the binocular microscope, it was possible to determine with some degree of accuracy about how much material had escaped. This is indicated in Figs. 1 and 2 by the solid black patch at the anterior end of the embryonic shield. The amount of material extruded varied somewhat in each experiment, the variations becoming more evident during the later stages of development. After the embryonic shield begins to appear, there is very little or no regeneration of the central nervous system and defects caused at this time consequently become more and more apparent as development proceeds.

²The artificial production of a single median cyclopean eye in the fish embryo by means of Sea Water Solutions of Magnesium Chloride. Arch. f. Entwicklungsmechanik der Organismen, Bd. 23, 1907.

³Science, Vol. XXVIII, p. 455.



FIGS. 13, 14, 15.—Experiment hm_1 . Operation on stage 1 (see Fig. 1). Eyes in contact in median plane.

FIGS. 16, 17, 18.—Experiment h_m . Operation on stage 1. Eyes fused, with two lenses and two cup cavities.

FIGS. 19, 20, 21.—Experiment ha_{11} . Operation on stage 2. Eyes fused with two lenses and one large cup cavity.

FIGS. 22, 23, 24.—Experiment h_{m1} . Operation on stage 2. Eyes completely fused with one lens and one cup cavity.

In a number of instances the material taken out with the needle point was from one side of the anterior end of the embryonic shield with the resulting absence at the time of hatching of the eye on that side. Fig. 6 shows the head of such an embryo, which was operated on at the stage shown in Fig. 2 and killed a few days after hatching, 15 days after the operation and 17 days after fertilization. The right eye consists merely of a small bit of retina remaining in the otherwise almost normal brain wall. The left eye is apparently normal as are also the brain and nasal pits. Figs. 7, 8, 9 are from another embryo operated on at the same time and stage as the one shown in Fig. 6, and killed 15 days after the operation. The sections show complete absence of the right eye, but with an otherwise normal brain and head. Figs. 10, 11, and 12 are from another embryo operated on at the same time and stage and killed 15 days later. In this embryo the left eye is entirely wanting, the fore-brain is slightly reduced in size and the nasal pits are quite close together. The right eye lies nearer the median plane than normal. See Figs. 3, 4, and 5.

Figs. 13, 14 and 15 are from an embryo in which the operation defect was about medial and done at a stage such as seen in Fig. 1. Fifteen days after the operation the embryo was pulled out of the membrane and killed. The two eyes are in contact, but each one is surrounded even at the place of contact with its own pigment layer. Two optic nerves are present and two lenses. The two nasal pits are in contact, but the brain is apparently about normal in size. Figs. 16, 17 and 18, from an embryo operated upon as above, show a median cyclopean eye in which the pigment layer is wanting between the two components. The two cup cavities are also slightly reduced in size. This fusion of the eye rudiments in the median line has taken place in such a manner as to separate the cranial from the facial portions at the anterior end of the head, contrast Fig. 17 with a similar view of the normal head, Fig. 4. Figs. 19, 20 and 21 show a somewhat similar cyclopean eye. The operation was done at the stage shown in Fig. 2, and the embryo killed 15 days later. The sections show a common cup cavity, the retinal and pigment layers forming a continuous wall about the cavity. There are two

lenses and two pupils, however. The lenses are in contact. There are also two distinct optic nerves. The brain is reduced in size and the eye separates it from the mouth region.

Figs. 22, 23 and 24 are from an embryo operated upon at a stage shown in Fig. 2 and killed 15 days later. Here is a single median cyclopean eye with one pupil and one lens and one cup cavity. A slight median notch on the anterior side of the optic cup indicates its origin from portions of two eye rudiments. The large optic cup shows in sections a very beautiful median eye with complete continuity of the layers of the retinas of the two components about a single large cup cavity and a single lens. The two nasal pits are in contact and lie dorsal to the eye. The brain is somewhat reduced, and its anterior end separated widely from the mouth region by the medially placed eye.

The explanation of the formation of these various abnormalities is in a way a comparatively simple one, if we assume that already in the early embryonic shield stage the various parts of the central nervous system and the eyes are, probably, already predetermined, and secondly that there is very little or no power of regeneration in this tissue. Numerous experiments on regeneration indicate very clearly that there is very little or no regeneration of the tissue (at least that of the central nervous system) extruded during the operation. The repair, taking place after the operation, consists merely of a rapid closing together of the parts left behind, and thus, a healing of the wound occurs without regeneration of lost parts. This closing of the wound is accomplished in a few minutes, and rudiments are thus brought into contact that normally are quite widely separated, those of the two eyes, for example. The subsequent differentiation adjusts itself to the new relations of these rudiments with the resulting abnormal forms. Thus as one examines these developing embryos, from the very first time the eye rudiments are visible in the living specimen under the binocular microscope, they appear to have the same amount of fusion or loss of an eye that is clearly to be found in the same individual at later stages and at the time of hatching. So we can explain these cyclopean forms through a fusion of the rudiments of the two eyes immediately after the

operation, even though at this time no rudiments are visible. Differentiation of the eye tissue evidently occurs sometime before it becomes visible by our crude microscopic methods.

Thus cyclopia in man can be explained through the influence of external factors acting during early stages of development in such a manner as to produce a single eye rudiment, and we need not seek for a germinal explanation. In these experiments on fish embryos, the eye rudiments were brought into contact and fused soon after the operation determining at this time the end result. There was not the formation of two eyes and then their subsequent fusion into a single median eye. It seems likely that in man similar early fusion of the eye rudiments must take place to produce cyclopia. These experiments throw no light, of course, on the cause of the early defect in man, although Stockard's experiments indicate that chemical factors might be responsible for such defective or altered early development.

The great similarity between these cyclopean forms and those produced by Stockard suggests that the $MgCl_2$ may have in some manner prevented the growth of certain cells at the anterior end of the embryonic shield during the embryonic shield stage. It is possible that the $MgCl_2$ solution might have the same effect on eggs subjected to its influence during and just preceding the formation of the embryonic shield.

OBSERVATIONS ON LIVING GROWING LYMPHATICS IN THE TAIL OF THE FROG LARVA.

BY

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From the Anatomical Laboratory of the Johns Hopkins University.

Recent studies have led to a distinct advance in our knowledge of the lymphatic system. Yet there are many points in which this knowledge is still incomplete. The observations here recorded seem to have a bearing upon some of these points, and hence seem worthy of presentation to the Association.

The studies were made on living frog larvæ; the species used were *Rana sylvatica*, *R. palustris* and *R. catesbiana*. Two devices were employed, both of which were essential to the success of the observations, an upright chamber and chloretone anesthesia. The former permits observations to be carried on with the larva in its normal upright position. Chloretone serves to keep the larva motionless while under observation. The use of chloretone introduces slightly abnormal conditions. Yet by alternating the periods of anesthesia with return to fresh water, the same larva may be kept under observation for several hours daily, for three or four weeks. During this time growth continues, though somewhat retarded.

In order to preserve accurate records of the various stages, drawings were made both with and without the aid of the camera lucida. The micrometer eye-piece was employed in making measurements. With the assistance of careful records, little difficulty was experienced in finding the same structures—blood-vessel, lymphatic, even connective-tissue cell—in successive observations.

The fin expansion of the tail of the frog larva, in early stages, is rather opaque, owing to the presence of pigment and yolk granules. During this period it is possible to distinguish the course of the blood-vessels only by the moving blood-corpuscles. Gradually this opacity diminishes, until eventually, at lengths which vary for dif-

ferent species, the tail becomes beautifully transparent. Now the walls of blood-vessels, individual connective-tissue cells, nerves, wandering cells and lymphatics may be readily distinguished, furnishing a picture of rare simplicity and beauty. Little wonder that it has been selected so often as a field for the study of elementary problems in anatomy! From this period an accurate record may be kept of the changes which take place, until the picture is again somewhat clouded by the development of pigment cells and by the increase in thickness of the tissues.

The blood-vessels first demand a short description. When the tail becomes transparent, they form anastomosing loops in both dorsal and ventral fins, extending outward from the edge of the axial mass. The limit of the vascular area is roughly parallel to the free edge of the fin and leaves a wide non-vascular area. Sprouts are sent out forming secondary plexuses which gradually approach the edge of the fin, so as to give a festooned appearance. Hand in hand with this new growth there is a general expansion of the tissue with an increase in the distance between neighboring capillaries. Accompanying these processes, adaptive changes take place in the older capillary mesh-work. Here some of the capillaries increase in size to form arterioles and venules, while others disappear. These disappearing vessels may be readily observed in all stages. The sequence of events in a single degenerating vessel is usually a stasis, so that a cell in the lumen remains in equilibrium—a narrowing so that no other cells enter—the appearance of a solid portion, which extends until the whole vessel becomes a solid cord—the breaking of this cord and gradual shortening of the two ends until the only vestige may be a slight swelling on the wall of the blood-vessel.

In no instance during these observations has there been seen a lumen-containing portion of a blood-vessel isolated from the actively functioning vessels. The relation between blood-vessel and lymphatic will be mentioned later.

The lymphatics in the tail of the frog larva have often been studied, by Kölliker¹ in 1846, then independently by Remak² in

¹Kölliker, *Annal. d. Sc. Natur.*, 1846.

²Remak: *Müller's Arch. f. Anat., Phys., u. wissensch. Med.*, 1850.

1850 and subsequently by numerous investigators, in the live animal, in fixed and in injected specimens. In our work, lymphatics were noticed during observations on the blood-vessels, as narrow, irregular, double-contoured structures with free ending toward the margin of the fin and traceable to the edge of the axial mass. They

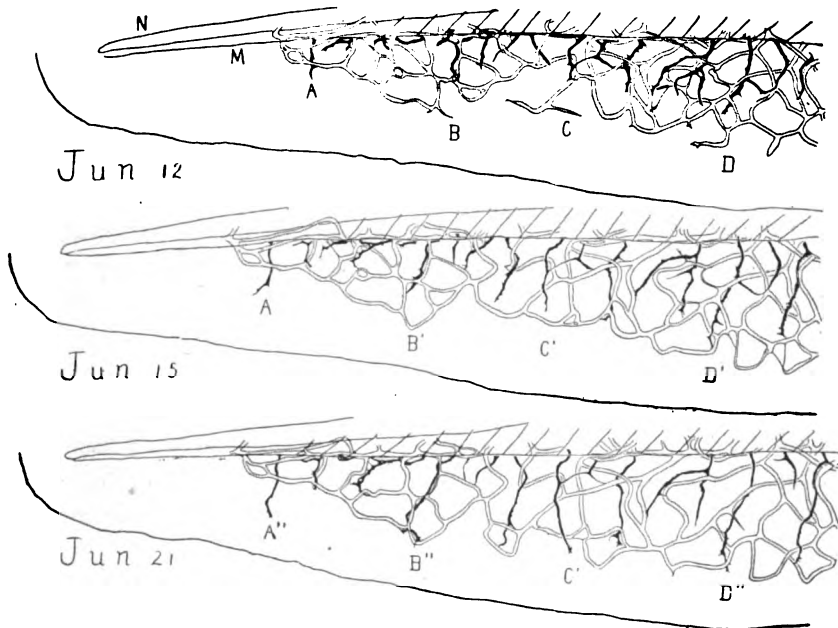


FIG. 1.—Three successive stages of growing lymphatics and blood-vessels in dorsal fin of *Rana catesbeiana* larva. $\times 30$.

Lymphatics in solid black, blood-vessels in lines. Vessels near tip are omitted. A, A', A'', etc., indicate same vessels in different stages. M., muscle edge; N., notochord.

appeared independent of blood-vessels. In order to be quite certain, injection was resorted to. With the aid of Dr. Knower's³ delicate injecting apparatus, a capillary glass tube with glass bulb to furnish pressure by air expansion, it was found possible to fill with India ink the vessels in question, quite independently of the blood-vessels.

³Knower: Anat. Rec., Vol. II, No. 5, Aug., 1908.

When the fin first becomes transparent, the only lymphatics to be seen are sprouts, some branched and some unbranched, often anastomosing with one another, extending out from under the cover of the axial musculature. They are of varying lengths, and in number correspond somewhat irregularly to muscle segments. Their tips stop considerably short of the limit of the blood-vascular area, so that we have three areas: a peripheral non-blood-vascular, non-lymphatic area, an intermediate blood-vascular non-lymphatic area, and a proximal area containing both blood-vessels and lymphatics, next the axial mass. As growth proceeds the lymphatics rapidly encroach upon the blood-vascular, non-lymphatic area, while both together grow into the non-blood-vascular area, until eventually the two systems are practically coextensive, reaching in older larvæ nearly to the fin border. During growth the primary anastomoses noted above disappear in part. Later there are gradually formed secondary anastomoses between neighboring capillaries. (Fig. 1.)

In a minute study of the growing capillary several questions at once present themselves. Does the lymphatic capillary grow out independently? What is its relation to blood-vessels, connective-tissue cells, wandering cells? Can we gain any clue as to the factors underlying the periphoreal extension of lymphatics—what is the stimulus?

If a single lymphatic capillary is selected for minute observation, it is found to present a characteristic appearance well described by Kölliker and Remak and well figured in Kölliker's *Gewebelehre*.⁴ The wall is of irregular thickness; most of it is extremely delicate, while at intervals are nuclear thickenings. In the earliest observable stage there are small globules in this nuclear area (yolk?), which soon disappear leaving a granular appearance. From the walls extend numerous fine pointed projections, at various intervals, and of varying lengths. The diameter of the lumen of the lymphatic is considerably less than that of the blood-capillary. The lumen always extends beyond the last nuclear thickening. The tip ends in one or more fine pointed processes, usually somewhat longer than

⁴Von Ebner, A. Kölliker's *Gewebelehre*. III, 1899.

the processes at the sides. Into the bases of the larger of these processes, the lumen of the lymphatic may be followed for a short distance. The tip is never bulbous but rather pointed or angular.

When such a living tip is carefully studied, an extraordinary phenomenon is noted, for it is found that the appearance of the capillary is perpetually changing. So complex are these changes that they almost elude description. Most noticeable are the changes in the

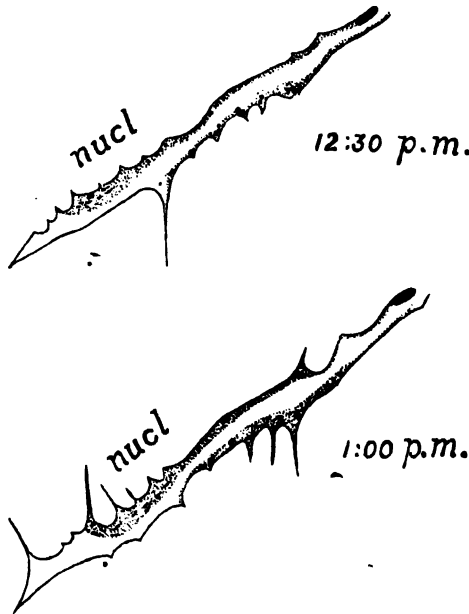


FIG. 2.—Successive drawings of same lymphatic tip in tail of *Rana catesbiana* larva, which had been stained with neutral red intra vitam. $\times 570$. Nucl., nuclear thickening.

contour of the lymphatic. The fine pointed processes already noted are not constant, they are continually appearing and disappearing. They vary much in length, some form mere short blunt projections, while others reach a length of many micra with all intermediate gradations. They may appear at any portion of the wall, including the nuclear area. The longer processes are usually seen at and

near the tip of the lymphatic, but not invariably—for occasionally long processes appear at the sides with those at the tip quite short. Just as they vary in length, so also they vary in the time of persistence. If careful drawings are made at ten or fifteen minute

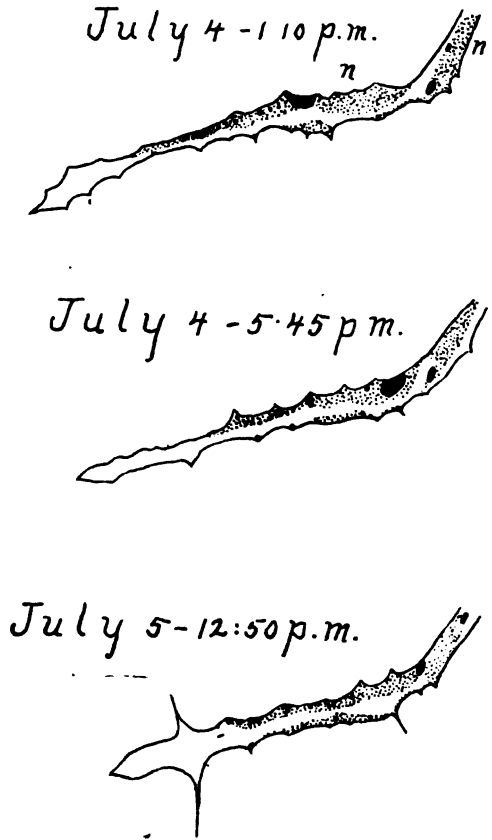


FIG. 3.—Same larva as in Fig. 2. Note shiftings of protoplasm of (n) nuclear thickenings as indicated by pigment granules.

intervals, in no two tracings will the pattern be identical. In fact, one gains the impression that were it possible to photograph the lymphatic at one minute intervals, careful study would reveal definite changes in successive pictures. Moreover, it is to be noted that these

observations were made on larvæ whose body processes were slowed by the use of chloretone. (Fig. 2.)

In addition to the unceasing change in the contour there are to be seen changes and shiftings in the wall. The nuclear thickenings are perpetually changing both shape and position. Now they appear crescent-shaped with the convexity encroaching on the lumen, again they become much elongated. Often the nuclear area is accompanied by a large black pigment granule. The nuclear thickening may shift its position relative to this pigment granule—being now at its proximal, now at its distal side. If a larva is stained with a weak solution of neutral red, there is a red granular coloration in the area of nuclear thickening. Later, instead of the red, there are to be seen here numerous small black granules. If a nuclear area containing these granules is observed closely, there will be noted a continuous shifting of the granules; sometimes several become grouped together, and again they separate. Two nuclear thickenings may appear in place of one,—and again two may appear to be moulded into one. (Fig. 3.)

While these changes are taking place, there may be, on the part of the capillary as a whole, a definite increase; or, more rarely, a decrease in length. The successive changes concerned in the increase are as follows: From a main lymphatic may be sent out numerous fine pointed processes. One of these processes persists and grows longer. As it increases in length, the lumen follows farther and farther into its base, until there is formed a short delicate-walled tube with one or two pointed tips, without a nuclear thickening. As this increases, gradually, from the wall of the main lymphatic, there passes into the branch a nuclear thickening. This whole tube now becomes longer and longer, the nuclear area passing further and further from the main lymphatic, but always remains at a distance from the tip. The lumen always extends beyond this nuclear thickening. (Fig. 4.)

After a time there appears in the wall a second nuclear thickening, and again a third and a fourth. These new thickenings seem to arise by division of the pre-existing ones, though definite proof of this has not yet been adduced by staining selected stages. Branches form in a

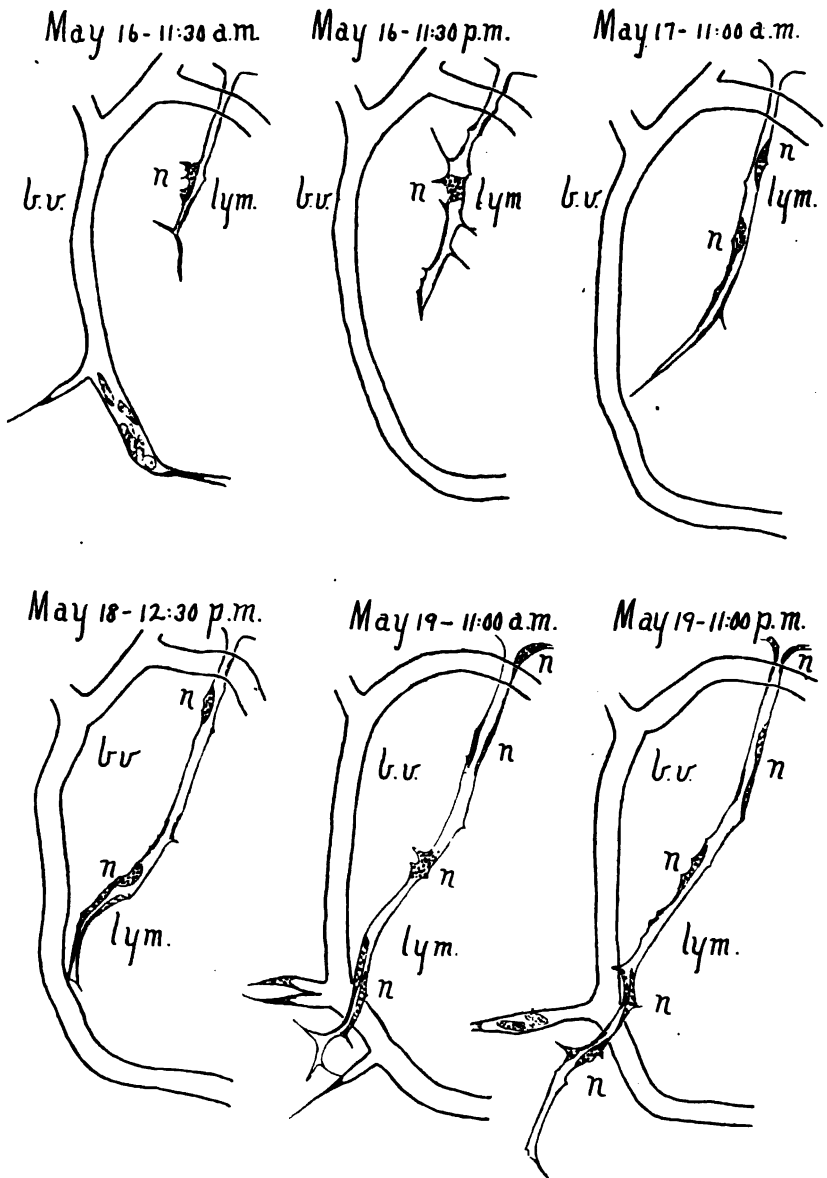


FIG. 4.—Successive stages in growth of lymphatic capillary in tail of *Rana palustris* larva. $\times 207$. b.v., blood-vessel; lym., lymphatic; n., nuclear thickening.

similar way. Anastomoses arise by the growing together of tips from neighboring capillaries or their branches, and appearance of a lumen in the solid connection thus formed. (Fig. 5.)

The shortening of a lymphatic capillary may be quite pronounced, for a branch which has attained the length of .2 mm. may be entirely withdrawn. The process of withdrawal has been studied less minutely than that of increase. It has been noted, however, that it takes

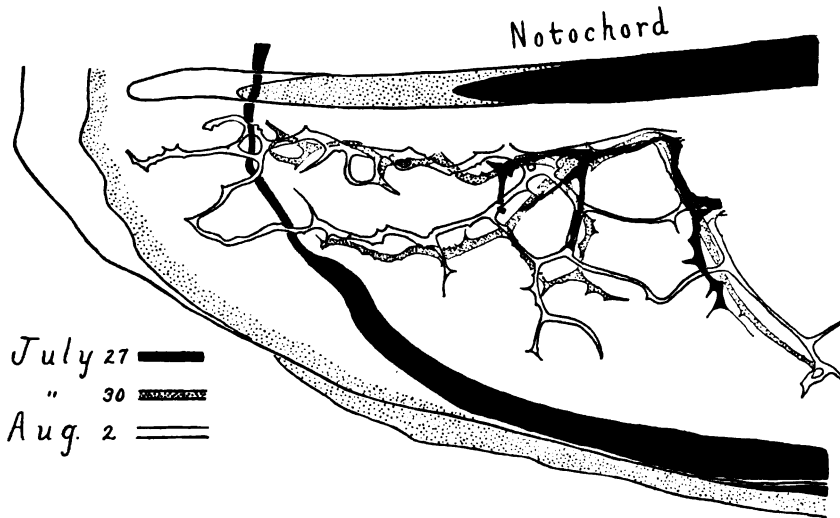


FIG. 5.—Three successive stages superimposed of lymphatics in tip of regenerating tail of *Rana catesbeiana* larva. Camera lucida drawing. $\times 82$. On July 21, about 4 mm. of tail of larva 12 mm. long was cut away. On August 2, regenerated part measured 3 mm.

place more slowly than does the increase; that two nuclear thickenings may approach one another; that the fine processes are shorter and less numerous; and that the lymphatic undergoing regression often ends in a long solid thread. In one instance such a long process contained a narrow lumen separated from the main lumen by a solid portion.

*Growth processes, especially branch and anastomosis formations, are well seen in a regenerating tail, for here the changes are more rapid than in the normal tail.

If we examine the growing lymphatic over a wide area, we find a continuous balance between neighboring sprouts. Of two or more sprouts which start in a new area, often only one increases while another may remain stationary or may be withdrawn.

Between neighboring sprouts which grow out to the fin margin the distance is fairly constant for any stage. As the larva grows, the tail expands in thickness and in length. The distance between neighboring lymphatic sprouts increases, and coincidentally there arise branches and anastomoses. For a time these all lie in the same sagittal plane. Later, in the thicker portions next the axial mass, branches may be seen extending toward either surface of the tail. As the lymphatic grows longer, the lumen of the more central portions increases in size, and thus the capillary becomes converted into a larger duct.

The relation between the connective-tissue cells and the growing lymphatic was carefully studied. These cells, with their numerous branched processes form a richly anastomosing supporting network. Unfortunately their finest processes are invisible in the living animal, so that the relation of these finest fibrillæ cannot here be determined. Of the visible processes, the smallest seem sometimes to extend to the lymphatic, yet whether they actually join the lymphatic cannot be decided beyond dispute. The larger of the visible processes appear quite certainly to be independent of the lymphatic capillaries. The main bodies of the cells are distinctly separate from the lymphatic. In a study of the growing lymphatic nothing may be seen which would even remotely suggest the bodily addition of one of these cells to the growing capillary.

Wandering cells are always present in the fin, usually well scattered. No connection was noted between them and the growing lymphatic.

The relation between lymphatic and blood-vessel was studied with great interest, for around this point many controversies have arisen. As noted above, when the tail first becomes transparent, the blood-vascular area extends beyond the lymphatic area. Later the two become practically coextensive. The growth on the part of each is an invasive one—as is readily seen by noting their relations to

selected fixed connective-tissue cells. During this invasion, however, the two remain totally separate.

Occasionally a lymphatic grows into an area in which no blood-capillary is present and in which none has been present. When the two are invading the same area, no regular relationship is maintained, for the lymphatic now runs parallel to and now crosses at right or oblique angle the blood-capillary. The lymphatic pays no attention to the new blood-capillary sprout, sometimes passing near by, and sometimes at a distance. Nor is the lymphatic influenced by the presence of the degenerating blood-vessels previously described. The entire process of degeneration may take place with no lymphatic near. Even when a lymphatic is near a degenerating capillary, no transfer of tissue may be detected. As no portion of a blood-vessel cut off from the main blood-vascular system has been observed, evidently there has been no opportunity for the growth of the lymphatic by appropriation of such a portion. Never have we observed an anastomosis between lymphatic and blood-capillary; or the direct passage of blood-cells from one to the other. In brief, all our evidence favors the absolute independence of the two systems in their peripheral extension. We thus differ from S. Mayer,⁶ who finds the lymphatics formed in part from the blood-vessels. Mayer quite certainly confused the true lymphatics with the constricted blood-vessels—a confusion easily possible when the larva is placed on its side beneath a cover-slip, and the electric current used to assist the anesthesia. For it has often been shown that both electrical and mechanical stimuli cause constriction of blood-capillaries in the tail of the frog larva.

In quite late stages Dr. Knower has noted that the lymphatics near the axial mass are very close to the veins. Our observations in the living lymphatic have not yet been carried to this stage, but we have seen the same in the relation between the ventral caudal lymph trunk and the caudal vein, in cross-sections of the tail. So close are these two that they seem to share in part the same wall.

⁶S. Mayer: Sitzungsber. d. kais. Akad. d. Wissensch., Wien, Abt. 3. Bd. 91, 92, 1885.

It is not surprising that such pictures have given rise to difficulties in the interpretation of cross-sections.

Thus far the changes in the lymphatics which seem concerned in growth have been considered, but there is another process which is going on simultaneously, perhaps inseparably connected with growth, perhaps the phenomenon at the basis of the growth, namely, functional activity.

By accident a few red blood cells were extruded from a new forming blood-capillary sprout into the extra-vascular tissue. To our astonishment two days later a lymphatic capillary had grown down to this group of cells and was seen taking them in one after another, without the agency of leucocytes. We had subsequently many opportunities to observe a repetition of this process, which deserves a careful description. The changes undergone by capillary and cell are extremely characteristic. From the lymphatic is sent out a fine pointed process, indistinguishable from the processes previously mentioned. This gradually extends to the blood cell. After coming in contact with the cell, the delicate tip is lost to view against the deeper colored blood cell and for a time the mode of procedure may only be observed by noting the changes in the shape of the blood cell. After the fine tip has been lost to view, there appears opposite the point of contact, a slight blunt projection from the blood cell. This projection gradually becomes longer until the cell is pear-shaped. The narrow portion is always paler than the remainder of the cell. Gradually this nose-like projection becomes longer, until the cell assumes an elongated oval shape as if in a narrow passage. Soon there appears beyond the cell, the tip of the lymphatic, slightly dilated, ending in a point. Slowly the cell moves centralwards and as it advances it is usually preceded by a short constricted area of lymphatic, while the portion between the cell and the tip is dilated. Gradually the cell passes along the lymphatic to the main caudal trunk, along which it advances with a steady uninterrupted motion, as if borne on by a definite stream. In one instance in which the cell entered the lymphatic quite rapidly, the tip could be seen for about a half minute distinctly open. (Figs. 6 and 7.)

If we arrange in order of intensity the reactions on the part of the

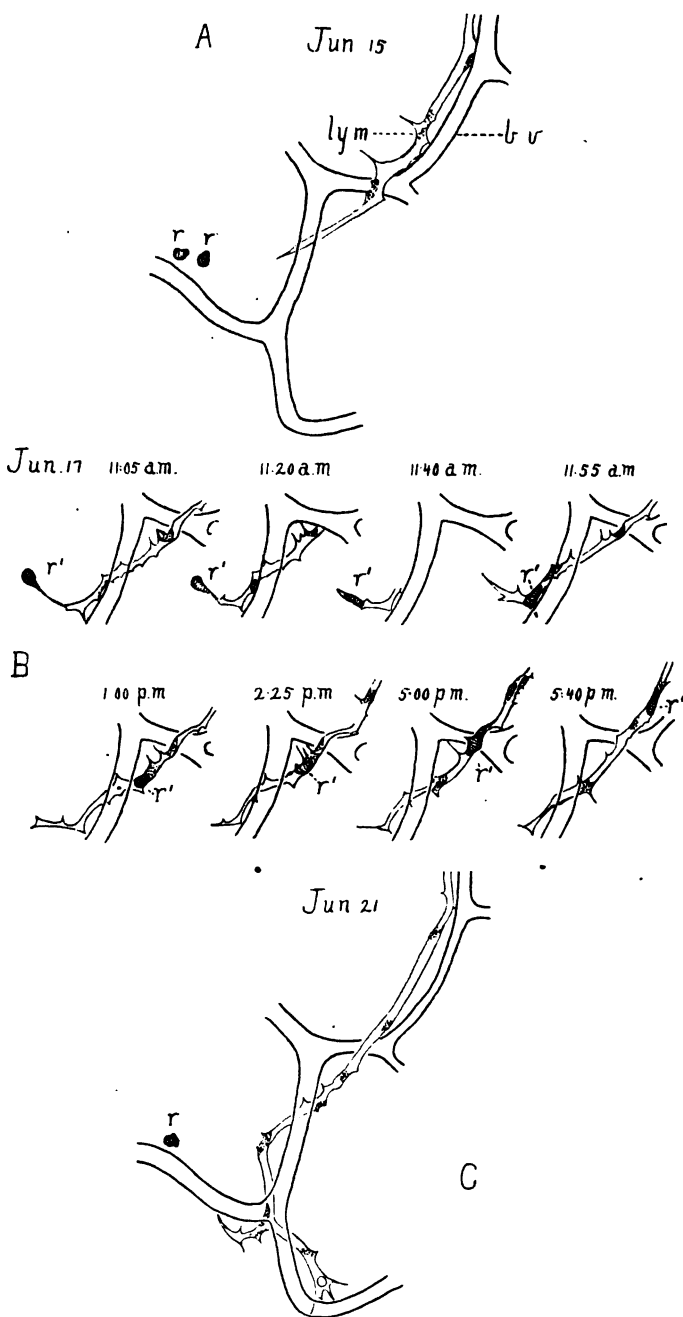


FIG. 6.—Successive stages in taking up of red blood cell by lymphatic capillary in tail of larva of *Rana catesbeiana*. $\times 163$. A before, B during, C after the process of taking up. r, r', two red blood cells, one of which (r') is removed, the other (r) left. lym., lymphatic; b.-v., blood-vessel.

lymphatic capillary as a whole to the stimulus caused by the presence of red blood cells in the tissue, we find the following series: If a single red blood cell is extruded, the lymphatic near by sends out a fine process, which takes in the cell and then disappears. If several

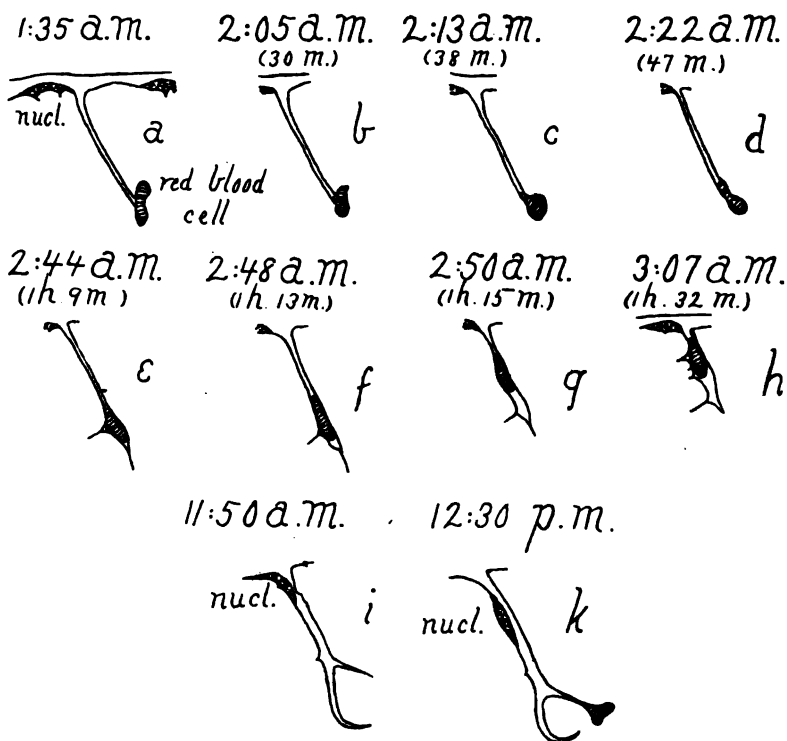


FIG. 7.—Successive stages in taking up of red blood cells by lymphatic capillary in tail of larva of *Rana catesbeiana*. $\times 275$. A group of cells was extruded at 9.30 P. M., June 13. Two hours later a lymphatic sprout was observed taking in one of these cells. This process was repeated until the extravasated cells were removed. Figs. a-h illustrate the taking up of one of these red blood cells. Between h and i, the larva was left in fresh water for 8 hours. i and k represent same sprout as shown in a-h. Note branch formation and moving down of nucleus.

cells are extruded near a lymphatic, the process takes in first one, then another, until all have been taken in. During this time it may increase somewhat in size, first without, later with a nucleus. If

several cells are extruded at some distance from a lymphatic, the sprout sent out may reach a considerable size, with a nucleus, before the cells are taken in. If a large number of cells are extruded near a lymphatic, the sprout sent out may branch, the cells being taken in through two or more processes. After all the extruded cells are removed, the lymphatic formed may remain or may gradually be withdrawn.

The function changes in the lymphatic capillary revealed by this series of accidental yet beautifully clear-cut experiments give us a suggestion as to the meaning of the growth changes described above. If we compare the two, we find a striking parallel. In fact, if, in the description of the taking up of the cells, we should substitute for "red blood cell" a substance microscopically invisible, and make the necessary changes, the two descriptions would be practically identical. Thus the changes concerned with peripheral growth and with function seem inseparably connected. We cannot avoid the suspicion that the fine processes continuously sent out represent a reaction of the lymphatic to ultra-microscopic substances, perhaps products of cell metabolism, that the greater the accumulation of these substances the longer and more persistent the processes, and that it is the varying formation of such substances which regulates the peripheral growth of the lymphatic capillary.

In connection with recent studies of the lymphatic system the tail of the frog larva furnishes an excellent field for testing methods. The two devices principally used have been injections and serial sections. Some confusion has arisen in the results obtained by these two methods. It has been suggested that this confusion has arisen from limitations of methods, yet they have not been subjected to rigid tests. In the fin expansion of the tail of the frog larva, where every lymphatic may be seen, a record may be made of the living non-injected lymphatics to serve as a control. The lymphatics may now be injected to see whether the entire system will be filled with the injection mass, or the tail may be cut into serial sections to see whether a reconstruction may be made which shall correspond with the control drawing.

A bull-frog larva (*Rana catesbiana*) 16 mm. in length has been used for the latter test. A drawing was made of the lymphatics and blood-

vessels during life. The tail was then cut into serial sections, ten micra thick and stained in hematoxylin and congo red. In attempting to reconstruct, it was found that, while blood-capillaries could often be fairly well reconstructed, it was impossible to reconstruct the lymphatics beyond the muscle margin. Further tests, however, are needed, with different stains, before definite statements are justifiable.

The injection method has been tested frequently and it is found that, while it carries us much farther than do reconstructions, the mass injected does not always fill the entire lymphatic system.

Let us now take a hurried glance over our results in their relation to present knowledge of the lymphatic system. Recent studies indicate that the first lymphatics arise from veins at various points. Of this primary origin we have made no test. As to the mode of extension of the lymphatic system into the different organs of the body, present views are divergent. Some observations lead to the conclusion that from several primary centers there is a centrifugal extension into the rest of the body, others that there is a transformation in situ of veins or mesenchymal tissue into lymphatics. The results here recorded are all in favor of the view that the peripheral lymphatics are formed by a process of centrifugal extension; that this extension, so far as relates to the endothelium, is strictly invasive, with no addition from connective-tissue cell, wandering cell or blood-vessel. Our observations indicate, however, that outside factors may exert a modifying influence on the growing lymphatic, that there is a close relationship between peripheral growth and functional activity. The question as to whether the lymphatic is open or closed is not definitely determined for all organs and tissues. The evidence here adduced favors a closed system of tubes, without direct openings into tissue-space or blood-vessel capable, however, of taking through its wall solid bodies of the size of red blood cells. But, perhaps most important, it has been demonstrated that the tail of the living frog larva, studied by special methods, furnishes an excellent field for the testing of problems relating to the growing and functioning lymphatic.

It is a pleasure to have this opportunity of expressing gratitude to Dr. Mall for his generous interest and numerous suggestions.

EXPERIMENTAL OBSERVATIONS ON THE DEVELOPMENT OF THE AMPHIBIAN EAR VESICLE.

BY

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University of Michigan.

The accompanying figure represents a reconstruction of the brain, eye and two ear vesicles of a tadpole about one month old, in which the experiment was made of transplanting the left ear vesicle to the right side in the space between the normal right ear vesicle and the eye. This experiment was made as a supplement to a series of



similar experiments showing the effect of change in environment upon the posture and development of the labyrinth, and which have been previously reported (*Jour. Exper. Zool.*, Vol. IV, 1907).

In the present experiment the effort was made to determine the influence of two adjacent ear vesicles upon each other; to see if on transplanting a very young ear vesicle, while still a simple primitive epithelial cup, and placing it against another similar ear vesicle, whether the two would fuse and develop into a single large labyrinth, as has been supposed to occur in cyclopia, or whether the transplanted vesicle would retain its individuality and continue to develop as a separate structure.

The experiment was carried out on *Rana pipiens* larvæ during the premitile stage, at a time when the ear vesicle consists of an invaginated epithelial cup just in the process of being pinched off from the deeper layer of the skin. The procedure adopted was similar to that used in the experiments previously mentioned; in this case the left vesicle being loosened from its natural bed and transplanted in a pocket in the loose tissue closely against the front

surface of the right ear vesicle. After the operation the specimen was reared and at the end of a month was killed in preserving fluid, embedded in paraffin and prepared in serial sections. A model was then made as shown in the accompanying photograph by means of the wax-plate reconstruction method of Born.

Examination of the sections and the model immediately shows that ear vesicles under the circumstances of this experiment maintain their identity. There is no trace of fusion or communication between the two. The experiment was repeated on other specimens and the specimens dissected with results to all appearances the same, though the duplicate specimens were not modelled. It may be pointed out that this result is in harmony with Stockard's recent experiments (*Science* p. 455, 1908), in which he produced cyclopia by the action of magnesium salts, and found that the defect was not due to a subsequent union or fusion of the two eye elements after they had become free and distinct. In all his cases where the cyclopic defect was present it could be recognized at the first appearance of the optic vesicles.

In addition to the original problem, the result of such a modification of environment upon the individual growth of the two vesicles is worthy of note. The effect produced upon the right labyrinth by the presence of the foreign one is limited to an abnormality of the anterior semicircular canal. A protruding pouch, corresponding to this canal, was formed in the normal way, but the central part of its walls failed to approximate and there was consequently no absorption area, such as is necessary for the completion of the closing off of the canal.

As regards the transplanted vesicle it can be seen, in the first place, that it has developed into a characteristic labyrinth. Furthermore the two canals, seen in the figure, possess the characteristics of the lateral and posterior canals respectively, that is, the labyrinth is a left-sided one. It may be pointed out that the distinction between the anterior and posterior canals can be easily made out by their relation to the lateral canal; the ampullæ of the anterior and lateral canals branch out together from the utricle like the two arms of a "Y," while the lateral canal is completely separated from the

posterior canal by a sharp cleft. Thus, in this instance the transplanted vesicle maintained its left-sided characteristics. It is next to be noted that, though in the transplantation it was placed haphazard as regards the planes of space, it has developed, like those described in previous experiments, in nearly a normal posture, with the endolymphatic appendage toward the brain. The tip of the appendage can be seen in the figure. The only serious defect in the transplanted vesicle is found in the region of the ampullæ of the anterior and lateral canals, where they press against the other labyrinth. The labyrinth wall here is markedly retarded in growth and there is a very incomplete development of the anterior canal. Otherwise we have two practically normal labyrinths, and both are connected with the brain by well developed separate ganglia and nerves.

THE EXPERIMENTAL METHOD AS APPLIED TO THE STUDY OF THE DEVELOPMENT OF THE NERVOUS SYSTEM.

BY

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Yale University.

No abstract of this paper is given here, as the paper itself in amplified form was published in *THE ANATOMICAL RECORD*, Vol. II, No. 9, December, 1908.

PAPERS AND ABSTRACTS.

COLORATION OF THE MILK IN LACTATING ANIMALS AND STAINING OF THE GROWING ADIPOSE TISSUE IN THE SUCKLING YOUNG.

By SIMON H. AND SUSAN PHELPS GAGE, *Cornell University.*

The following is a report of progress in experiments with food mixed with Sudan III.

The first step reported was in 1896, when Daddi found that Sudan III fed to animals, colored growing adipose tissue red.

The next was Riddle's report during Convocation Week a year ago that Sudan III fed to laying hens reappeared in the yolk of the developing egg.

Last July we found that in chicks hatched from such colored eggs the adipose tissue was of the characteristic Sudan pink. The fact of transmission of this coloring matter from mother to offspring was presented before the Graduate School of Agriculture in July and printed in Science of October 9, 1908.

As this substance can be transmitted from mother to offspring in a bird, it seemed that there might also be a similar transmission in mammals.

White rats were used, these responded at once to the feeding. The adipose tissue of half grown animals of both sexes showed the pink color when first tested, that is within five and seven days. As our animals were all immature, we sought the aid of The Wistar Institute.

Dr. J. M. Stotsenburg, who has direct charge of the rat colony at the Institute, undertook the necessary experiments for us. He mixed Sudan III with the food of pregnant rats, and continued the experiments during a considerable period; but the new-born rats have not as yet yielded a trace of the Sudan that we could detect either by visual examination of the minute fat masses present in the body at birth, or by ether extracts of those masses.

Further experiments were carried on for us by feeding the mother rats food mixed with Sudan III during the first eight days after

the birth of their young, that is during a time in which only the mother's milk is used by the young as food. At the end of eight days the young rats showed an abundance of pink adipose tissue, and the milk filling the stomach was so pink that it showed clearly through the stomach wall.

This foreign substance then not only colors the adipose tissue in the adult but also colors the fat of the milk, and the young living upon this pink milk has its growing adipose tissue colored.

As Sudan III gives the adipose tissue in the living animal what might be called a mass coloration easily recognized by the unaided eye, or with a simple magnifier, but is not satisfactory for microscopic investigation, we adopted the suggestion of Dr. Stotsenburg and turned from the rat to the guinea-pig in which the fat masses are well developed at birth.

Through the kindness of Dr. Theobald Smith of Harvard University and his assistant, Herbert R. Brown, guinea-pigs were fed the sudanized food during the last half of gestation. One specimen fed 13 days gave birth to offspring in which, as usual, much fat was present. No Sudan color could be seen and on extracting 4.5 grams with ether no color was obtained. Five other new-born specimens from sudanized mothers were examined, but in no case could the characteristic color be found in the adipose tissue.

While in the hen the Sudan III is transmitted to the young through the yolk, and in the rat through the milk, contrary to our expectations neither the rat nor the guinea-pig fed during gestation showed transmission of this substance through the placenta.

DESCRIPTION OF A 5 MM. HUMAN EMBRYO. BY H. E. JORDAN, *Adjunct Professor of Anatomy, University of Virginia.*

The material upon which the following contribution is based is a human embryo 5 mm. in greatest length. The specimen, for which I am indebted to Dr. Stephen H. Watts, Professor of Surgery, came into my hands in normal salt solution two hours after hysterectomy. It was immediately transferred to 95 per cent alcohol. Subsequent measurement showed a shrinkage of 1 mm. The specimen was stained in toto in Delafield's hematoxylin and sectioned at

10 microns. The tissues are excellently preserved and the degree of development is very similar to that previously described for embryos of approximately this length. Thus in respect to the vascular and alimentary systems, it appears similar to embryo No. 148 of the Mall collection (length 4.3 mm., myotomes 28) carefully studied by Mall,¹ Bardeen and Lewis² and more recently by Mrs. Gage;³ and to embryo G. 31 of O. Hertevig's collection (length 4.9 mm., myotomes 35) studied and described by Ingalls.⁴ It differs markedly, however, from these embryos in respect to the brain and the nephric system, the difference probably representing a slight advance in development. In external form it appears similar to embryo R of the His⁵ collection (length 5 mm., myotomes 35), and is probably of about the same age, *i. e.*, between 22 and 24 days.

I have been able to procure the following history of the case: The woman was 33 years of age and had previously had four children, the youngest of whom is 9 years old, and two miscarriages. Menstruation had been regular. Her last period began September 16th. The operation was performed October 27th.

The above dates leave an interval of 13 days between the first omitted menstruation and the time of operation. The minimum and maximum ages of the embryo are probably about 21 and 25 days, respectively. Fertilization must have occurred at least 12 days after the last menstruation or at least 8 days before the omitted one. These data indicate independence of ovulation and menstruation.

External Form.

The following points are important concerning the external appearance: The head turns slightly to the right and the tail to the left (see text figure). The umbilicus appears to be median. The nuchal bend is almost a right angle. There are 35 (perhaps 36)

¹Mall, F. P., Johns Hopkins Hospital Bull., xii, 1901.

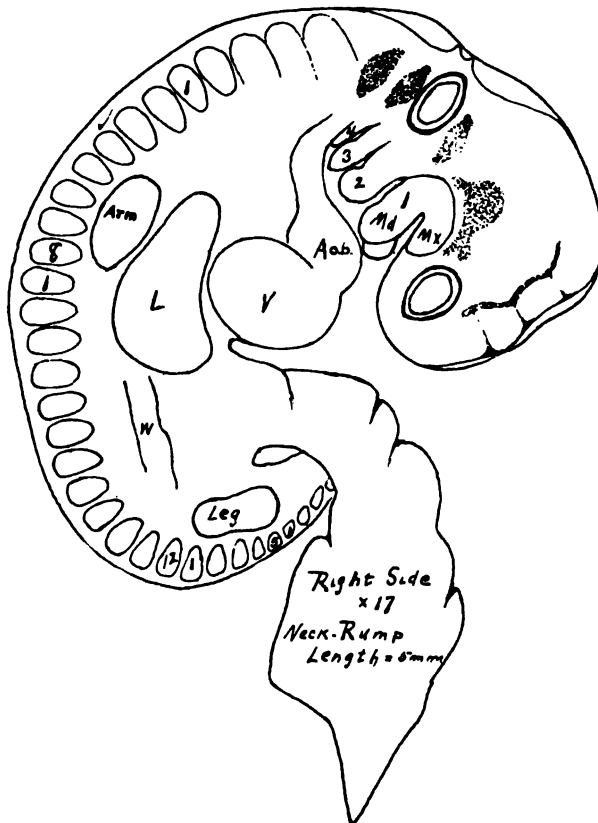
²Bardeen, C. R., and Lewis, W. H., Amer. Jour. Anat., 1901.

³Gage, S. P., Amer. Jour. Anat., IV, 1905.

⁴Ingalls, N. W., Archiv f. Mik. Anat., lxx, 1907.

⁵His, W., Anatomie menschlicher Embryonen. Text and Atlas. Leipzig. 1880-1885.

somites (1o, plus 8c, plus 12t, plus 5l, plus 5s, plus 4 or 5c). External corrugations simulate segmentation anterior to the single occipital somite. The sections show that these represent remnants of three additional occipital somites. The arm-buds extend from the 4 to 8 cervical somite inclusive; the leg-buds from the 1 lumbar to the 1 sacral inclusive. The left arm-bud is turned back, thus presenting



its medial face. Four gill-arches appear externally; a fifth lies within the sinus praecervicalis. The maxilla is just beginning to take shape.

Three corrugations appear on the anterior face of the diencephalic region. The extent of the thin roof of the fourth ventricle is plainly visible. In the mid-region there is a small notched ele-

vation of folded ectoderm. Eye, ear, auricle, ventricle, bulbus and truncus arteriosus, liver, Wolffian ridge and ganglia (5, 7 and 8, 9, and 10) are also visible externally. Anterior to the maxilla, the ectoderm of the ventral face of the head is very thin and slightly depressed. On changing the level of focus one sees in this region a sucker-like projection with median groove and central indentation. Sections show that this is the region of the optic recess, and the indentation probably marks the site of final closure of the neuropore.

The ectoderm consists generally of a single layer of cuboidal cells. Ventral to the eye on either side of the head occur patches of thickened ectoderm extending through 24 sections representing the anlagen of the nostrils. Thickened patches of ectoderm occur also in relation to the cranial nerves forming so-called "placodes." Sections show that the somites have differentiated into sclerotome (with loose anterior and denser posterior segment) and myotome. The otic vesicles lie between the base of the third gill arch and the ectodermal fold of the roof of the fourth ventricle above mentioned.

INTERNAL STRUCTURE.

(a) *Alimentary canal*.—The mouth forms a broad transverse slit bounded laterally by the mandibles and maxillæ, anteriorly by the fore-brain and posteriorly by the fused mandibles. No remnants of an oral plate can be found. The mouth leads into a broad wide pharynx bounded laterally by the gill arches. Between the latter are the entodermal extensions of the pharynx, or gill pouches, forming with the apposed invaginated ectoderm thin membranes stretching between the arches. A dorsal cephalic extension of the pharynx is the anlage of the hypophysis, posterior to which lies a second extension of the pharynx, Sessel's pocket. Closely applied to the curved anterior border of the hypophysis, rests a projection from the diencephalon, the infundibulum. In this same region the notochord terminates with a sharp ventral curve.

On the floor of the pharynx in the region of the second arch the tuberculum impar is well developed. The alveolo-lingual grooves and the lateral rudiments of the tongue are not well marked in the sections. In the same region the median thyroid, unconnected

with the pharyngeal epithelium is present, consisting of a small irregular mass of spheroidal cells. Anlagen of lateral thyroids and the thymus are just recognizable in the sections.

The larynx, represented merely by a slight depression, leads into the trachea, about one half millimeter in length, which bifurcates into two branches each with a terminal expansion. The latter are enclosed by extensive mesoderm forming the lung-buds.

The pharynx leads into a short œsophagus with thick epithelial wall and narrow lumen. On the dorsal border of the liver, the tube enlarges slightly, forming a short spindle-shaped stomach. This in turn leads into the duodenum with wider lumen and finally into the caudal intestines. About the level of the fourth thoracic somite the vitelline duct arises. The gall-bladder and bile-duct lie on the lower border of the liver ventral to the intestine. About 50 microns anterior of this point the anlage of the dorsal pancreas can be recognized as a shallow outpocketing. The intestine can be traced to the cloaca, which is closed by the anal plate. From the cloaca the allantois extends outward into the umbilical cord. Proximally the allantois shows a slight expansion, the anlage of the urinary bladder. Pericardial and pleural coelon are continuous dorsally with the abdominal coelon. The liver has grown out in all directions into the septum transversum. The hepatic tissue is invaded by the omphalomesenteric veins forming sinusoids.

(b) *Vascular System*.—The heart appears very similar to the His model for a 5 mm. embryo. The two atria are continuous, forming a single large sac with lateral expansion, and opening by the atrial canal into the left ventricle. The sinus venosus has moved to the right. The left ventricle passes into the bulbus arteriosus which makes a sharp turn dextrally and cephalward, and passes into the truncus arteriosus which extends along the ventral aspect of the atrial part of the heart. The wall of the heart consists of a loose mesh of undifferentiated muscular tissue. The wall is thickest in the left ventricle. The endothelial tube is loosely applied in the heart proper, but more closely in the bulbus and truncus arteriosus.

The truncus passes into the floor of the pharynx where it expands into a wide sinus. From the latter extend two anterior branches (ventral aortal) each with two lateral twigs. The most anterior of

these breaks up into capillaries in the mandible and the second supplies an aortic arch to the second gill-arch. From the sinus, and projecting backwards arises the larger third aortic arch. Caudally from this point the fourth and sixth aortic arches take origin. Slender backward extension of the ventral aorta behind the sixth arch supply capillaries to the floor of the larynx. The aortic arches on each side unite dorsally to form two dorsal aortæ which in turn unite about the level of the fifth cervical myotome, or the cephalic border of the liver, into the single dorsal aorta. Just anterior to this point the subclavian arteries, and immediately beyond it the celiac artery, are given off.^a

A large ventral branch, the right omphalomesenteric or superior mesenteric artery leaves the dorsal aorta at about the level of the fifth thoracic myotome. Near its termination it bifurcates into two branches which accompany the vitelline duct for a short distance on either side. The inferior mesenteric artery arises as a delicate ventral branch about the level of the seventh thoracic myotome. The dorsal aorta again divides into two (the hypogastric or umbilical arteries) before it passes into the umbilical cord. Frequent renal twigs are supplied to the glomeruli of the Wolffian ridge. From each dorsal aorta there extends cephalad a twig (internal carotid) to a short distance beyond the hypophysis. The vertebral arteries can be traced forward as far as the diencephalon.

The jugular veins (precardinals) arise from the union of numerous twigs lying close to the surface in the anterior head region. Posterior to the eye, where the vein becomes an elongate vessel, it passes mesad of the gasserian ganglion and laterad of the ganglia of the 7th and 8th nerves and the otic vesicle. Ramifying within the ganglia of the 9th and 10th nerves it passes laterad of the former and mesad of the latter and unites with the duct of Cuvier. The umbilical veins arise at the umbilicus from a single large vessel and thence forward through the somatopleure to the Cuvierian ducts. The ductus venosus, formed by the union of the vitelline veins in

^aI am unable to find any evidence of multiple subclavian arteries such as Evans (Evans, H. M., ANATOMICAL RECORD, Vol. 2, No. 9, 1908) reports from embryo No. 148 of the Mall collection (two segmental vesicles), and as I have myself observed in very young turtle embryos (three segmental vessels).

the liver, also connects with the sinus venosus. A single vein, the "primary ulnar" (subclavian) drains each arm-bud. The leg-bud also contains only one vein, the "primary fibular" or "vena ischiadica" (common iliac). All blood vessels and the heart contain well preserved erythroblasts; occasionally these are seen in mitosis.

(c) *Nephric System*.—In the nephric and central nervous systems the greatest variations are found between this embryo and the several above mentioned. The Wolffian ridge extends from the level of the mid-region of the arm-buds to the cloaca. Anlagen of the genital ridge and metanephros have not yet appeared. The Wolffian ducts appear continuous from end to end of the ridge. There are approximately 30 nephric tubules. The anterior 18 or 20 consist of well-developed glomeruli with Bowman's capsule connected by patent S-shaped tubules with the Wolffian duct. Several of the most anterior glomeruli lie very close to the cœlomic epithelium; the remainder lie deeply embedded within the ridge. The tubules have comparatively thick walls and narrow lumen. The posterior 12 or 14 end distally in expanded vesicles, but no true glomeruli have formed; and these tubules also are connected with the Wolffian duct. Several delicate tubules at the cephalic end of the ridge which are difficult to trace in sections may represent the remnant of a pronephros. However, no tubules connect either with the cœlom or the myotomes. The nephric system at this stage consists essentially of a mesonephros apparently considerably less generalized than that of the embryos described by Mrs. Gage and by Ingalls.

(d) *Central Nervous System*.—The eyes at this stage are represented by evaginations from the diencephalic margin of the fore-brain and are already slightly cupped. The ectoderm has thickened into a plate of tall cells over the region of the cup forming the anlage of the lens. The posterior roots of the spinal nerves are represented by delicate bundles of neuroblasts. The wall of the neural tube, which consists of an internal ependymal layer of tall cells, a middle layer of neuroblasts and a peripheral marginal velum, appears in the sections to have a perfectly smooth internal contour. Study of a carefully constructed model of the brain (by the blotting paper method described by Mrs. Gage in the ANATOMICAL RECORD for November 10, 1907) together with the sections disclose the following

conditions: Externally the brain tube gives no clear evidence of folds. As already stated, however, three ectodermal corrugations appear in the region representing the diencephalon and the mesencephalon; and the same number appear anterior to the occipital somite. The fact that these latter corrugations correspond to occipital somites in process of disappearance shows that metamerism had at an earlier developmental stage extended into the region between the first cervical and vagus nerves. The ganglia of the 5, 7 and 8, 9 and 10 nerves are symmetrical in position and similarly developed except that the right gasserian ganglion is considerably larger than the left. The segmental arrangement of ganglia indicates a still more anterior extension of metamerism. When one regards a slight external bulging just anterior to each gasserian ganglion as the "cerebellar folds," and the ganglia of the 7 and 8 nerves as a fusion of two segments, and the region of the otic vesicles as the fifth "neuromere" the full number considered typical (seven) for the mammalian hind-brain (Bradley⁷) is accounted for. In six distinct regions, also, there is a decided thinning of the neuroblast layer of the wall of the hind-brain and a reciprocal thickening (in sections conforming to a blunt wedge-shaped area) of the marginal fibre layer corresponding more or less closely with ganglia of the 5, 7 and 8 nerves, the otic vesicle, and the ganglia of the 9 and 10 nerves. Moreover, there is in these regions the merest indication of a bulging of the wall. In the model, however, one seeks in vain for distinct evidence of folds, with the exception of a wide embayment in relation to the gasserian ganglion. This "neuromere" is by various writers on different forms described as the most pronounced and least transitory fold. I can find no evidence of distinct internal folds in the fore and mid-brain. The foregoing facts seem to indicate, then, that my embryo has attained to a slightly later stage of development than that of the embryos described by Mrs. Gage and by Ingalls. It seems probable, accordingly, that folds anterior to the gasserian ganglion have already disappeared, as also those related to nerve roots posterior to this region including the vagus. The only persisting "neuromere" at this stage is the one associated with the trigeminal nerve, or the second of the rhombencephalon.

⁷Bradley, O. C., *Rev. Neurol. and Psychiatry*, II, 1904.

A STUDY OF PATHOLOGICAL CAT EMBRYOS. BY H. E. JORDAN. *From the Anatomical Laboratory of the University of Virginia.*

The science of descriptive teratology is founded mainly on facts relating to the embryonic pathology of man. Recently, Denison (1) made a study of ten abnormal pig embryos and reported results in harmony with the conclusions of Mall (2) regarding the origin of merosomatous human monsters. The results of a microscopic study, which I am making of diseased cat embryos, are thus far also strikingly consonant with recent opinion respecting the etiology of human terata.

Schwalbe (3) regards "amniotic constrictions and bands" as among "the most abundant of anomalies of the amnion" and states that "abnormalities thus produced are manifold" (p. 192-193). Mall in his article on "The Origin of Human Monsters" says, "No amniotic bands are found in any of the 169 specimens which I have studied." Denison likewise finds no amniotic bands in pig embryos, but the "amnion is often thickened, rough and smaller than normal." Ballantyne (4) in summarizing his chapter on "Amniotic Diseases in Teratogenesis" says that in the case of some of the terata at least, "the amnion would seem to act by pressure, and so delay, or altogether stop the progress of events in ontogenesis."

In one horn of the uterus of a cat I found two embryos measuring 12 mm. and 9 mm., respectively, and in the other horn one embryo measuring 7 mm. The first two embryos with their adnexa appeared normal. The third embryo was enveloped in a closely fitting amnion which was adherent to the uterus over a wide area (Fig. 1). The amnion had formed a band extending across the body between the two limb-buds, and the constriction associated with the band had produced a partial separation of the posterior from the anterior portion of the embryo. Three additional minor constrictions of the amnion produced adhesions with the ectoderm of the head, fore-limb and the body-wall in the region of the heart. The eyes were faintly visible externally. No sign of somites could be recognized. The head appeared considerably swollen. The embryos and a portion of the uterine wall were immediately fixed in Zenker's fluid.

The first striking fact is the great variation in length between em-

bryos from the same uterus and probably of the same age. Professor McClure, who has studied many cat embryos, in his work on the development of the venous system and lymphatics, writes me that from 1 to 1.5 mm. is the greatest difference he has ever noted. He says, moreover, that he has not found many embryos with amniotic bands. In the case under consideration one naturally infers that the amniotic band interfered with the nutrition of the smallest

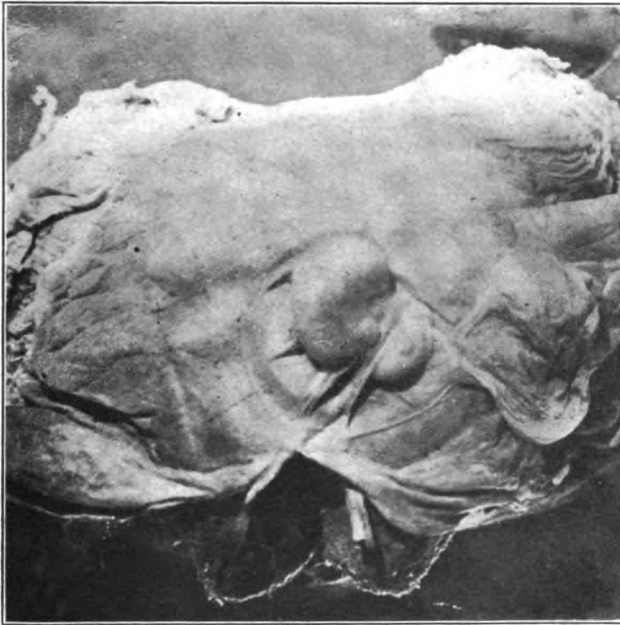


FIG. 1.—Photograph of 7 mm. cat embryo showing the area of fusion between the closely-fitting amnion and the wall of the uterus; also the deep amniotic constriction between the limb-buds. Magnification about 3 diameters. (Made by Prof. Theo. Hough.)

embryo and prevented normal growth. However, the difference of 3 mm. between the larger embryos indicates the influence of a more primary malevolent factor. I undertook a comparative study of the pathological embryo with the amniotic band and the two apparently normal embryos from the same uterus. The sectioned material showed that all three embryos were similarly pathological

though in varying degrees, thus indicating a common fundamental inciting cause.

The above facts combined with others even more obvious, make

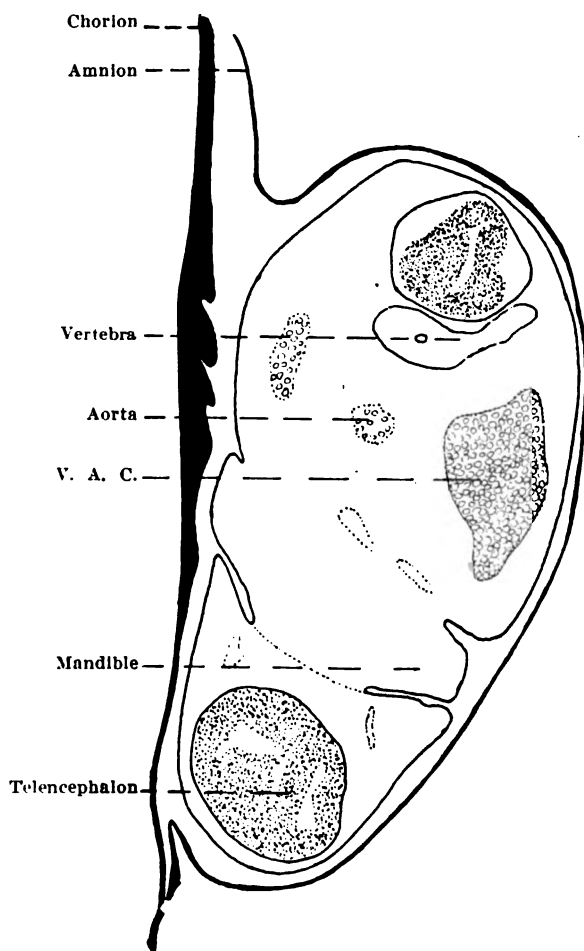


FIG 2. Semidiagrammatic drawing of transverse section through region of fore-brain showing solid cord and brain (the unstippled areas represent an acidophile coagulum); also the engorged right anterior cardinal vein (V. A. C.).

it improbable that the union between amnion and chorion represents an incomplete original separation. The union is intimate

(Fig. 6), but is probably due to secondary fusion following amnionitis. A better understanding of the early development of the cat would aid in distinguishing a primary from an acquired adhesion. The problem is complex, since, in early stages, there is an allantois-amnion, an allantois-chorion, and a yolk-sac placenta. (O. Schultze) (5).

Both amnion and chorion have become much thickened in places, and both may perhaps be best described by the term "fibro-cystic" adopted by Denison for apparently similar changes. Cells with large fragmenting nuclei lie in the cyst-like interstices of the chorionic mesodermal tissue. The cells of the amnion are for the most part smaller, the fibrous tissue is less compact, and the lacunæ are wanting. Sections of the uterine wall show that chorionic villi are present and apparently normal in some regions, while in others they are covered with an exfoliating epithelium or are absent. In short there is evidence of necrosis, but no sign of inflammation.

Neither umbilical cord nor vesicle is present. The embryo appears attached directly to the amnion and chorion (Figs. 3 and 4). Extreme strangulation evidently obtained, centering about the point of entrance of the blood supply of the embryo. Since there was no endometritis, the pathological condition may be the result of the "faulty implantation" (Mall) or some other elusive cause producing "disorderly ontogenesis". (Ballantyne.)

Sections of the 7 mm. embryo reveal the following points: The embryo is much deformed in the facial region. A portion of the head has fused with the wall of the thorax thus obliterating the mouth and involving the base of the tongue (Fig. 2). However, the mandible, maxilla and two gill-arches can be distinguished. No distinct epidermal ectoderm can be recognized. The left fore-limb has turned upward (dorsalward, Fig. 3) and rests over a thickened area of the chorion. Caudalward from the fore-limb, the body-wall is much deformed (Fig. 5). In the region where the amniotic band has not cut through the entire body-wall, the internal organs are much compressed and misshapen (Figs. 4 and 5); they have been invaded by blood cells. Still more posteriorly the remains of chorionic villi appear with exfoliating epithelium and necrotic areas.

The brain and spinal cord are enlarged and almost solid. Their cavity is filled with a mass of coagulum and round cells, probably derived from the dissociating nervous elements. No wandering

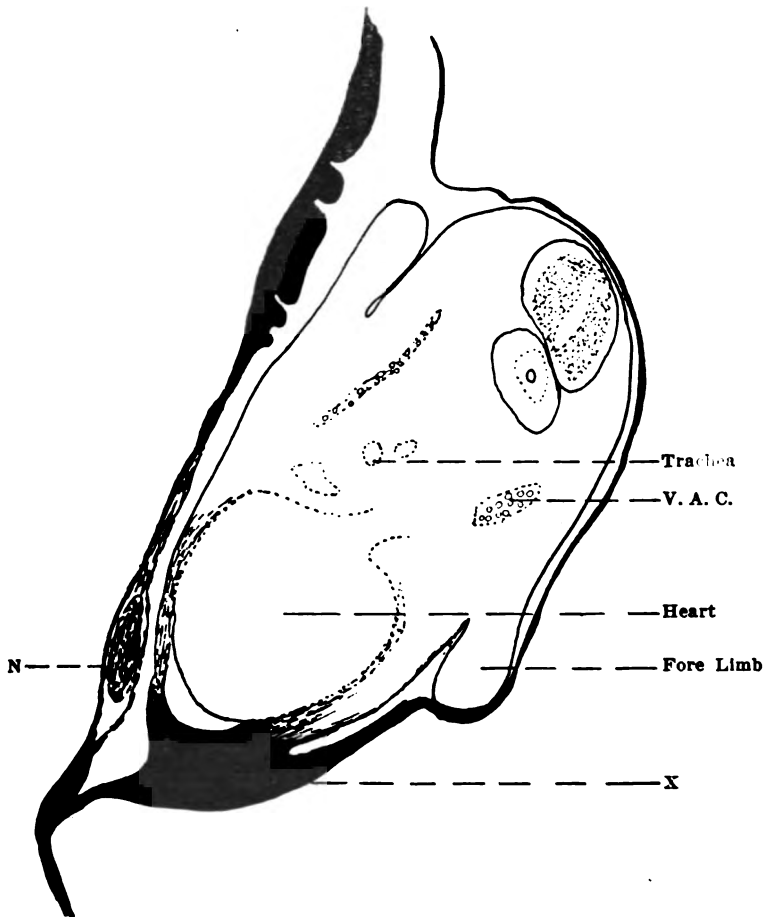


FIG. 3.—Semidiagrammatic drawing of transverse section through the region of the fore-limbs and heart, showing a necrotic area (N) in the chorion; also the area of fusion between body-wall and amnion (X) and the fusion of heart with body-wall and the amnion with the right fore-limb. $\times 20$.

blood cells are present. The nerves are merely masses of pale disintegrating fibres, and the ganglia are in process of dissociation.

The epithelium of the ear has broken down and the cells are disintegrating. The eye appears as a confused mass of broken elongate cells (the product of the dissociating and disintegrating

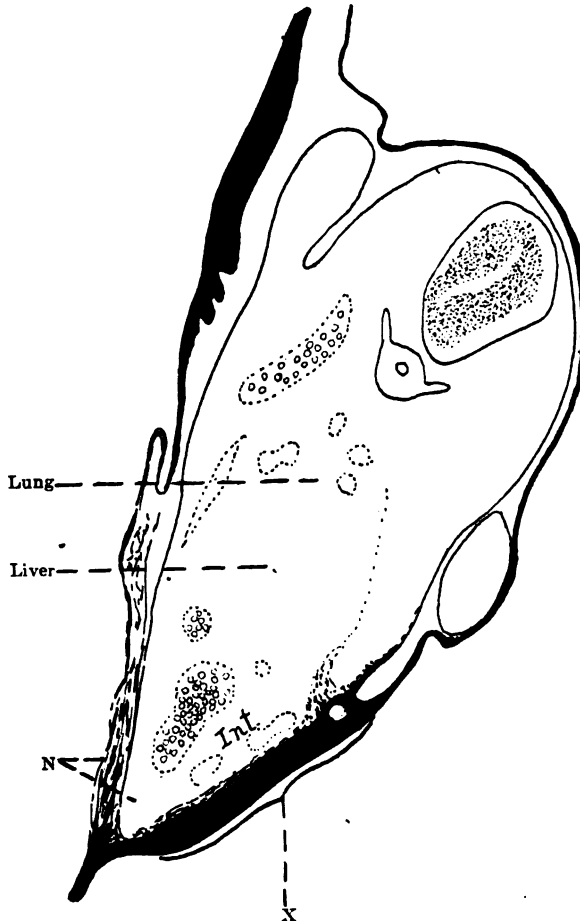


FIG. 4.—Drawing of region 85 sections posterior to the last, showing enlarged area of fusion (X) between amnion and body-wall, and the strangled condition of the blood vessels and intestines in the region of the umbilicus. $\times 20$.

lens), surrounded by a layer of dissociating retinal cells, and by large pigment granules (the residue of disintegrating choroid cells).

The epithelium of the trachea, œsophagus, stomach, duodenum and mesonephros is also detached from its basement membrane and

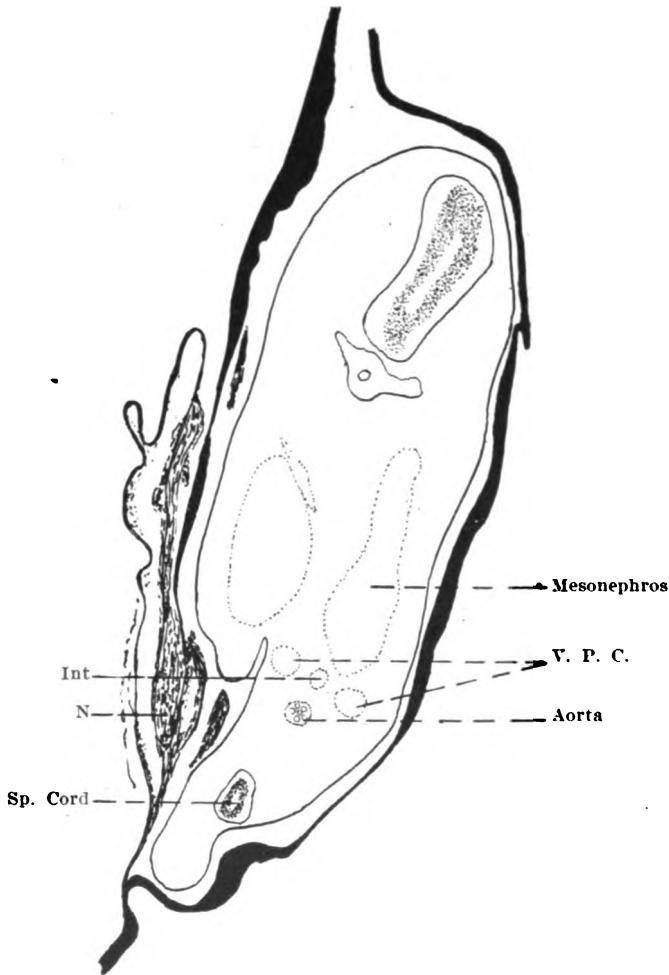


FIG. 5.—Drawing of section through the mesonephron and the associated posterior cardinal veins (V. P. C.), showing also the thickened character of the amnion and the malformation due to pressure of the amniotic band. $\times 20$.

dissociating. The liver is represented merely by an amorphous mass of round hepatic cells mixed with blood cells (Fig. 4). The

pharynx is small; the infundibulum, thyroid gland and thymus are dissociating.

The aortic arches are very small and filled with dissociating endothelial cells. The blood vessels and the heart are filled with blood. The right anterior and posterior cardinal veins are much dilated and engorged with blood. (Fig. 2.) In a few cases the walls of the blood vessels have disappeared and erythroblasts have wandered

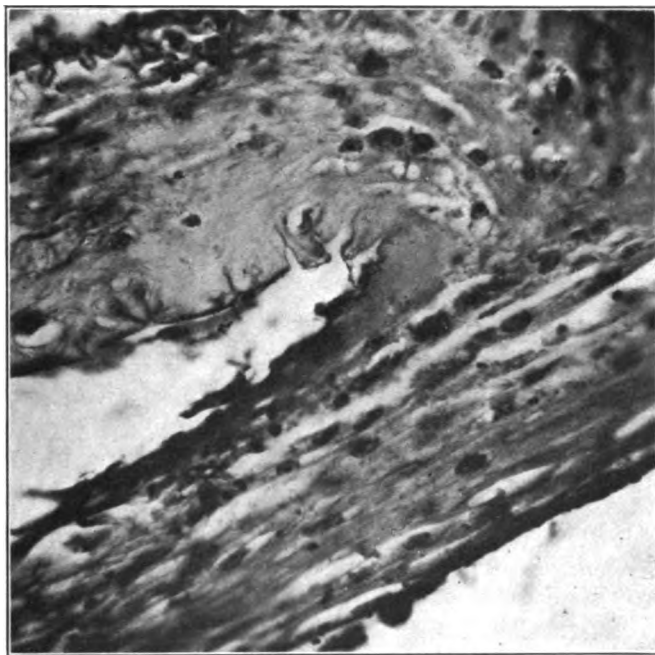


FIG. 6.—Photomicrograph of region of fusion between amnion and chorion. $\times 300$. (Made by Dr. Frank P. Smart.)

into the surrounding tissues. Many of these have fragmented nuclei. The heart appears almost normal, though the atria are small and irregular and there are signs of tissue dissociation.

In the head region the mesenchymal tissue seem œdematous and the nuclei of the cells are fragmented. In other regions the mesenchyme appears generally in healthy condition. At points of fusion between the embryo and the amnion the mesoderm seems

continuous from one to the other. In the region of the heart the body-wall has fused with the amnion over a wide area (Fig. 3), and the heart has fused with the mesenchyme of the body-wall.

Myoblasts are sparsely scattered here and there through the dorsal regions of the body. Precartilaginous and cartilage everywhere appear normal. The notochord is in process of dissociation.

Sections of the 9 mm. embryo show similar pathological changes, though it is plain that the embryo has attained a slightly later stage of development. There is a smaller area of fusion between amnion and chorion. The umbilical cord is very short and compressed, and the yolk-sac has disappeared. The embryo is misshapen and flattened in the region of the umbilicus. In the oral region and the spinal cord the embryo is more nearly normal. But again the brain is solid, enlarged and filled with round cells; the epidermal ectoderm is lacking; ganglia, nerves, eyes and epithelial linings are dissociating.

The liver is a confused mass of large round cells. The walls of the blood vessels have very generally disappeared and the blood cells have invaded the tissues. The aorta and aortic arches are filled with dissociating and probably proliferating endothelial cells. Myoblasts are more numerous, but never aggregated in myotomes. Mesenchyme and cartilage again appear perfectly normal.

The 12 mm. embryo has attained a considerably later stage of development, but similar diseased conditions prevail in the tissues, apparently with great severity. There is no blood in the heart or vessels. The walls of the vessels have disappeared. The tissues including the brain are invaded with nucleated blood cells. Here also the brain and cord are solid. The area of adhesion of amnion to chorion is very small; but there is undoubted strangulation and consequent interference with nutrition. The face in the region of the mouth is much misshapen. All the tissues except cartilage and mesenchyme have dissociated as in the other embryos. Myoblasts are very numerous and individually they appear in good condition. There are regions where mucoid degeneration has taken place. All the organs belonging to this stage of development are present, but dissociating, the liver, brain and blood vessels being most seriously affected.

SUMMARY.

The stage of development is inversely proportional to the area of adhesion between amnion and chorion or to the degree of strangulation. Barring the deformity due to the pressure of the amnion and the presence of an amniotic band in the 7 mm. embryo, the degree of abnormality varies slightly but directly as the development, as indicated more especially by the character of the blood vessels. Since the three embryos of the same uterus are similarly diseased and since only one has an amniotic band, the latter can only have been secondary to some underlying more primary cause. This was not endometritis, but some other pathologic agent producing necrotic areas in the placenta, destruction of chorionic villi, fusion of amnion and chorion, strangulation of the cord and interference with nutrition. Another interesting fact is the selective influence of the disease-producing factor on the various tissues. Liver, brain, cord, nerves and blood vessels show progressively less susceptibility to the morbid agent in the order named. Mesenchyme and cartilage seem most resistant. The pathological cat embryos agree among themselves and with certain human and pig embryos in being hydrocephalic and œdematous, with tissue dissociation and local histolysis. The results of this study support the position of Mall respecting human embryos that amniotic bands are secondary factors in the production of merosomatous monsters.

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REMARKS ON THE DYES USED IN THE HISTOLOGICAL LABORATORY.

By ROBERT RETZER, *Anatomical Laboratory, John Hopkins University,*

An effort to arrange the dyes used in this laboratory, so that not only the members of the staff, but also the errand boy should have no difficulty in finding them and putting them back to their proper places, was found to be a more difficult task than it seems at first sight. The dyes are known by English, French and German names and translating them into the terms of one language is but the first step. Most dyes have compound names and the question then arises, "Under which name shall they be classified?" The problem was solved by arranging them alphabetically according to the colors indicated on the bottle. Where the color was not mentioned (dahlia, fuchsin, etc.) the bottles were placed in an alphabetical order interspersed between the other bottles. With this method of classification, the dyes were not misplaced and a great deal of annoyance obviated.

Before coming to the decision of adopting this manner of arrangement, it was considered whether it would not be advisable to place synonymous dyes together, with a view of thus utilizing the old stock. To my surprise, this turned out to be an impossible labor.

What according to one author is a synonymous dye means according to another an entirely different one. This, in turn, led me to look into the literature more thoroughly and study the origin of the names and the constitution of the dyes we use. For reference, I used the *Encyklopädie der mikroskopischen Technik*, Mann's *Physiological Histology*, Bernthsen's *Lehrbuch der organischen Chemie*, Nietzsche's *Organische Farbstoffe*, Beilstein, the chemical dictionaries of Watts and Thorpe, and the catalogues of Grüber and of Merck.

Even the cursory examination of a few of these books will reveal the lamentable state of our knowledge of the dyes. No two authors seem to agree, a fact readily understood when we consider that one is a chemist, another a histologist, another a manufacturer or dealer. The confusion seems to arise with the manufacturer who caters to the demand of the dyer and calls the product he sells by the name of the dye from which it is derived. For instance, *Echtgrün* is dinitroresorcin to the chemist, while one manufacturer

places the sodium salt and another the potassium salt on the market as *Echtgrün*. Frequently it is still more confusing and complicated. The chemist applies the name to the base while the histologist buys a salt of its sulphonic acid under the same name. I might have stated that the histologist not alone suffers from the impositions of the manufacturer. If the chemist wants pure methyl alcohol in his laboratory he calls for Columbian spirits, if he asks for methyl-alcohol he is not sure to get a pure product.

In tabulating¹ the synonyms of the dyes used by histologists, and there are about three hundred names to be found in biological literature, one is beset by a grèat many obstacles due to the inaccuracy of the authors. Each one stretches the synonyms a little further, until by comparing the first with the fifth author we find two entirely separate and distinct dyes called by the same name.

So, for instance, *helianthin* becomes *crocein 3 B*, *dahlia* (sol. in water) becomes *anilin violet* (insol. in water) and *alcohol blue* becomes *primula*. The confusion of terms is partly due to the histologist who will dissolve a dye in water that is according to all the authors insoluble. Evidently he used a different dye from the one he mentioned. In this paper, I intend to present but a few of the most commonly used dyes and point out some of the errors we fall into.

Hæmatoxylin, the dye obtained from the wood of *Hæmatoxylon campechianum* (logwood), is spoken of by the older German authors as *Blauholzextrakt* or *Campeschaholzextrakt*. The crystals are colorless and are but little soluble in cold water. They oxidize very rapidly by exposure and become *haemateïn* and some other oxidation products, that are more soluble. It follows from this that the solubility depends upon the age and exposure of the *hæmatoxylin*.

¹The tables contain: First, the name of the dye; second, all of its synonyms and pseudonyms; third, the chemical formulae of each of these; fourth, the manufacturer; and fifth, the process of manufacture or its derivation. Rows 1, 2, and 3 of the tables are fairly complete, but 4 and 5 are necessarily incomplete, because the manufacturers' catalogues were inaccessible. The size and incompleteness of the tables prevent me from having them published. They form, however, the basis of this study, which has extended over a period of six months.

and when making up a saturated solution it must be taken into consideration.

Eosin is probably the next most commonly used dye and is manufactured by a great many German, English and American factories. Whenever this is the case the products differ in their physical and chemical properties, because these dyes are not made for the chemical laboratories, but for dyeing and staining. Eosin is derived from fluoresceïn, the sodium salt of which is occasionally used in histology under the name of uranin. When fluoresceïn is treated with bromium it forms among the bromium compounds tetra-bromfluoresceïn, called by chemists eosin. We buy the sodium or potassium salt under the name of eosin, Eosin gelblich, Eosin w. gelb, or water-soluble eosin. The pure tetra-bromfluoresceïn is practically insoluble in water, however.

The alcohol soluble eosins are the ethylethers or methylethers of tetra-bromfluoresceïn. The former are but little used in histology, while the latter we buy under the name of methyl eosin, primerose and Spriteosin. Kaiserroth, saffrosin, phloxin, Bengal rose, Eosinscharlach and Lutetienne have been called synonymous, but wrongly. They are iodine, chlorine or other compounds of tetra-bromfluoresceïn.

By erythorosin is meant an alkali salt of either tetra- or di-iodide fluoresceïn. We may get a sodium salt, potassium salt, or ammonium salt of tetra-iodide fluoresceïn, and the same salts of di-iodide fluoresceïn, and mixtures of all. The difference in results we notice by solubility and color reaction. Unless we get the stain from the same bottle we are never sure to get the same result the second time, because we deal with arbitrary mixtures and not chemical compounds.

- | | | |
|---------------------|-----------------------------|-----------------|
| 1. Basic Fuchsin. | 6. Rosanilin. | 11. Anilin Red. |
| 2. Neutral Fuchsin. | 7. Rosanilin hydrochloride. | 12. Azaleine. |
| 3. Fuchsiene. | 8. Solferino. | 13. Harmaline. |
| 4. Magenta. | 9. Rubin. | 14. Rubianite. |
| 5. Magentaroth. | 10. Erythrobenzine. | |

These are the names which are given as synonyms of fuchsin. The one most commonly used in this country and England is

frequently spoken of as a separate and distinct dye. Histologists recommend magenta for staining the inner substance of elastic fibres, but fuchsin for a nuclear stain. The dealers naturally make stock of this and we find the two names in their catalogue. The original magenta was an English manufacture, while fuchsin is made in Berlin and Elberfeld. We find frequent errors, especially in every-day parlance, made in the opposite direction. Histologists will speak of sudan, when they mean sudan III, pyronin when pyronin G or pyronin B is meant, and methyl violet when they mean any one of six or seven dyes that are put on the market.

A word about the methyl violets and the use of numerals and letters. Methyl violets are oxidization products and are the mixtures of hexa-methyl-para-rosanilin with penta, tetra, or even di and nono-methylpararosanilin. The salts are called methyl violet 6B, 5B, 4B, etc., the numerals indicating respectively the preponderance of 6, 5, 4, etc., methyl groups. Methyl violet 6B, therefore, is frequently called hexamethyl violet. Just as the methyl violets are the methylated rosanilins (or fuchsins) so the anilinblues are the phenylated rosanilins. With one or two phenyl groups the color is violet, with three or more blue. There are more than twenty anilinblues mentioned in histological literature. Most authors do not state which anilinblue they have used, and it is, therefore, little wonder that other histologists fail to get the same results.

Every person who has worked with methylene blue knows of the inconstancy of the results. The main cause of this lies in the impurities. There are various methods of manufacture and each method brings in a different impurity. Knowing what chemists can do, I am convinced they can put a pure methylene blue on the market for the use of histologists. As soon as we get a pure stain we must discard all the others, because the results obtained from them are but empirical. I have frequently heard the term methyl blue used synonymously for methylene blue, more from carelessness than from ignorance, but as it is just such carelessness that brings the vast number of pseudonyms into literature, it is worth while calling attention to it.

What conclusions must we draw from these observations? What can be done to give us more uniformity in the matter of dyes?

It seems a hopeless state of affairs and even an optimist can find little pleasure in the contemplation of the problem. First of all, we must be more careful in the use of names. When we use eosin we must state what kind of eosin, that is, we must be explicit and not use class names such as methylene blue, anilin blue, etc. Secondly, we must state whether it is the sodium, potassium or ammonium salt. If we do not know, then stating the manufacturer's or dealer's name will be of some use. To-day we know the process of manufacture of most of our dye-stuffs, as the patents have long expired, and when we find out the manufacturers' name we can also conclude what the most likely impurities are. I may here say that it is immaterial whether we consider staining a chemical or a physical action. We well know that the solubility of a salt is not dependent on the chromofore radical, but upon a number of undetermined factors, and where some stains are done with a watch in the hand, the concentration of a solution is very important.

To-day nearly every histologist is a dyer, as soon as he uses stains he belongs to the same class as the silk manufacturer and dyer. Histological staining is to-day unscientific, or if we dignify it by the name, let us call it an empirical science. As long as we do not know the nature of the reagents we are dealing with, histological staining is to-day where medicine was a hundred years ago. We must do away with empiricism if we want to learn something about the principles underlying all structures.

Yet, staining has once and for all time become a necessary adjunct to our histological course and our own researches, and it is not my intention to suggest a sweeping reform, but to advocate the elimination of a great many evils connected with it. Every teacher knows that it is difficult to demonstrate to a student the form of it when the nucleus or cell is unstained, yet it can be done and it trains the student's power of observation. We must not forget that there are so many artefacts connected with staining that we do not always get a true picture of the structure when we study it stained. Staining has very little to do with morphology, it deals with far more complicated phenomena, which will never be approached until the histologist learns that he must not only know that a given dye will stain a nucleus blue, and another protoplasm

red, but that he must also know what its chemical constitution is. There are a great many dyes that have formed the basis of chemical work, of whose physical properties we know something. The histologist can have more, if he demands more. How can he learn anything about the physical properties of a gland or of a cell if he is ignorant of the essential properties of the reagents he uses?

To repeat, staining has very little to do with morphology. Sufficient evidence is given by the progress of histology. We can use Stricker's Handbuch to-day, and learn all of the essentials; indeed, a number of facts we find in it have been forgotten and rediscovered. And this book was written before the introduction of anilin dyes. It is hard to recall any great discovery with the exception of Ehrlich's and his followers, that has been based on the reaction of cells to dyes. The discoveries were made by the physiologist, who pointed out certain physiological actions of cells, glands or tissues, and these discoveries were only verified by the histologist. With all the complicated methods for staining the nervous system we have only managed to verify the work or suggestions of the physiologist. The dispute about the structure of ganglion cells and nerve-endings will not be settled until we put staining on a sound physical basis.

This seeming digression was necessary in order to make clear the conclusions. It is every evident that the histologist is being imposed upon by the manufacturer of dyes, and this imposition is due mostly to his ignorance and stands in the way of progress. The study of the synonyms has led us to get at the root of the evil. There are, as far as I have been able to find out, about ten factories from which we get our dyes. Each one of these factories turns out a product which is intended to stain blue, green, violet, etc., but not to have definite chemical reactions, and the name which the manufacturer gives, means something to him but nothing to us. We have, chemically speaking, a number of synonyms for a great many dyes, but practically—practically to the histologist—there are no two dyes alike. This evil must be remedied.

We owe to Weigert and Ehrlich the science of histological staining, which is still in its infancy. Because it is a difficult task it needs the *combined* efforts of all histologists to place this science

in the same rank with the others. The efforts must at first be directed towards the obtaining of pure products. As soon as we have these, and not before then, can further discussions be legitimately introduced. Not so many years ago the chemists were in the same predicament and had to purify practically every reagent with which they worked. They *could* purify them because they had the appliances and the knowledge, but the histologist cannot do so to-day. It may mean that eventually the histological laboratory will have its chemical division, but in all events that lies in the far future. We must consider the present, and so the histologist should use only those dyes of which the chemist has found the constitution, and of which the most likely impurities and their influence upon the reaction are known. Even those histologists who do not believe in the importance of chemistry must admit that to-day it is difficult, sometimes impossible, for a man to obtain the same results in this country as another gets in France or Germany. This applies especially to results obtained from the newer stains, with which the market is being flooded. It may be unscientific to consider the protection of American industry, but we certainly could get products fresher and quicker by patronizing American dye manufacturers. Competition is great enough to make the insistence upon purity tenable. To-day we get impure products because there is no demand for other.

We must therefore—

1. Exercise more care in the use of names, because carelessness is the prime cause of misleading pseudonyms.

2. Insist upon the name of the manufacturer, if not his, then the dealer's, because each manufacturer means a definite dye when he puts it on the market, and does not consider that other dyes carry similar names.

3. Give the chemical formula, so that there be no misunderstanding and our work can be repeated and verified by other observers.

4. Require pure products, made for the use of the chemist and histologist and not the dyer, and following this, require a standardization of dyes.

THE ORIGIN OF THE SEX-CELLS OF AMIA AND LEPIDOSTEUS. BY
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It has been shown in a number of papers that have appeared during the last fifteen years, that sex-cells of representative fishes, amphibians, birds and reptiles undergo a more or less extensive migration from the position in which they are first distinguishable, in order to finally come to rest in the sex-gland anlage.

The papers of Wheeler, '99, on *Petromyzon*, Woods, '02, on *Acanthias*, King, '08, on *Bufo*, Jarvis, '08, on *Phrynosoma*, and Allen, '06-'07, on *Chrysemys* and *Rana* have each shown with greater or less certainty that the sex-cells arise in the endoderm, and that they migrate from it up through the mesentery to the sex-gland analgen.

Striking differences in these processes, as seen in *Amia* and *Lepidosteus*, are extremely interesting. In *Amia* the sex-cells arise from the endoderm a short distance lateral to the junction of that portion forming the roof of the subgerminal cavity, with the vitelline mass. Further work may show a more extensive anlage. From this zone they pass up into the lateral plates of mesoderm, in which they migrate toward the axis of the embryo, passing along between the splanchnic and somatic layers. On account of their large size and the large size of the yolk particles with which they are filled, they are clearly distinguishable from the mesoderm cells. Furthermore, the nuclei are larger, paler and more rounded than are those of the mesoderm. These characters also serve in a lesser degree to differentiate the sex-cells from the endodermal cells of the alimentary tract, which they approach as they near the goal of their migration. Most of the sex-cells undergoing this migration reach the medial ends of the lateral plates of mesoderm before the splanchnic and somatic layers separate to form the body cavity. When this does occur, the sex-cells remain attached to the peritoneum in such a way as to occupy a position a short distance on each side of the root of the developing mesentery. As the two mesodermal layers separate, the sex-cells are very clearly seen to lie between them, only later sinking into the proximal portion of the somatopleure—the sex-gland anlage. The sex-cells are found in the mesoderm opposite the hind-gut, in a region beginning with its anterior end, and extending backward about five-sixths of the distance to the cloacal opening.

It will be seen from the above account, that this process, as it occurs in *Amia*, shows conditions almost identical with those described by Woods and Beard in the Elasmobranchs and less fully by Hoffmann in several species of birds.

In *Lepidosteus*, on the other hand, the sex-cell migration is strikingly different in many important features. The sex-cells are distinguishable only at a much later period of development than in *Amia*. They are first to be seen in the endoderm of the hind-gut, becoming clearly distinguishable only when the yolk material of the surrounding cells has become so far absorbed as to more sharply reveal the cell boundaries and at the same time render the yolk-filled sex-cells more distinct by contrast with their neighbors. The sex-cells at this time (embryo of 7.5 mm. length) are found in the endoderm of the hind-gut, from its proximal almost to its caudal end,—chiefly in its lateral and dorsal walls. They differ from the ordinary endoderm cells surrounding them, not only in their much greater yolk content, but also in their greater size and in their very distinct and well rounded cell outlines. There are at this time no striking nuclear differences between the two classes of cells.

When the embryo attains a length of about 8.5 mm., the sex-cells begin to migrate from the gut endoderm up into the loose mesenchyme, dorsal to it. This migration continues for a considerable period—embryos from 8.5 to 9.5 mm.—until all but relatively few of the sex-cells have left the endoderm. During this period, the lateral plates of mesoderm gradually split to form the body cavity, and by the slow approximation of the splanchnopleuric plates, the mesentery is being formed. As these splanchnopleuric layers approach one another from both sides, they gradually compress between them the loose mesenchyme in which the sex-cells lie, until finally when the larva has reached a length of about 12 mm., the tissues have become so condensed and the mesentery so narrow that it would seem no longer possible for the sex-cells, remaining behind in the endoderm, to migrate through it. While the mesentery is slowly forming, the sex-cells are migrating up through it to finally come to rest in the sex-gland anlagen on each side of its dorsal end (*radix mesenterii*). Some very clear instances were found, in which these

sex-cells showed definite amœboid form. This seems to indicate their mode of progression. In *Lepidosteus*, as in other forms studied, some sex-cells go astray, never reaching the sex-gland anlage. In the oldest stage studied, sex-cells were seen lying in the endoderm and mesoderm of the intestine.

In a recent paper upon *Bufo* by Miss King, '08, and a slightly earlier paper of the author's upon *Rana*, the sex-cells were shown to migrate *en masse*, instead of singly as in *Lepidosteus*. Aside from this, the sex-cell migration of these two amphibians shows striking points of similarity with that process as observed in *Lepidosteus*, in that the sex-cells are first recognizable in the endoderm, in which they undoubtedly have their origin; furthermore, they migrate at the time when the mesentery is forming. In *Rana* and *Bufo* on the one hand, and in *Lepidosteus* on the other, the sex-cells are quite similar in appearance; this applies to relative size, yolk content and sharp boundaries. The absence of indications of cell division, during the migration process, is characteristic of the sex-cells of all vertebrates studied.

In a previous paper, '06, I showed that the sex-cells of the turtle (*Chrysemys*) arise on each side of the caudal half of the embryo in the extra-embryonic endoderm at the junction of the area opaca with the area pellucida, and that they migrate medially from these anlagen, continuing in the endoderm as they do so—pushing their way among the surrounding endoderm cells to a position immediately beneath the axis of the embryo. From this point they migrate dorsally through the developing mesentery to the sex-gland anlagen.

This process is essentially like that observed in *Lepidosteus* and *Rana*, with the difference that the sex-cells in *Chrysemys* can be easily traced back into the early stages, when they are seen to lie in the *extra-embryonic* endoderm. It is quite probable that further investigation in *Lepidosteus* and *Rana* may show a more or less extensive migration within the endoderm from more lateral anlagen to the median line beneath the mesentery.

The sex-cell migration in *Acanthias*, as set forth by Woods, differs from the corresponding process in *Chrysemys* only in the fact that in that form the sex-cells migrate from their anlagen into the meso-

derm immediately above, in which their further migration is accomplished. In Wheeler's, '99, very suggestive work upon *Petromyzon*, he shows that the sex-cells arise at some distance on each side of the axial plane of the embryo in a region where the lateral plates are not yet split off from the endoderm. When the splitting is finally carried to such a point as to involve the sex-cell anlagen, the sex-cells adhere to the mesoderm, through which they finally migrate to the sex-gland anlagen. While this is true, they closely resemble the endodermal cells, their large size and great yolk content being in sharp contrast with the small size and small yolk content of the mesodermal cells, among which they lie. I think, as Wheeler suggests, that we are justified in considering this to represent a very precocious migration from the endoderm into tissues potentially mesodermal.

However striking these differences may be, they are not of fundamental importance. The really important generalizations, toward which these facts point, are (1) That the sex-cells are formed in the endoderm in the forms mentioned in this paper, in some forms certainly, and in others possibly, at some distance on each side of the median line. (2) They migrate from these anlagen to the sex-gland anlagen. This path may carry them either through the endoderm or through the mesoderm. (3) This migration is so timed that the sex-cells pass through the anlage of the mesentery at the time when it is forming. However interesting from a morphological standpoint it may be to ally the sex-cells with the endoderm, I do not wish to have it understood that I deny the specific character of the sex-cells in contradistinction to the somatic cells. Experimental work may ultimately help us in distinguishing between them, even though they show no visible morphological differences in early stages.

ON THE GROWTH OF THE ALBINO RAT (*MUS NORVEGICUS* VAR. *ALBUS*) AFTER CASTRATION. By J. M. STOTSENBURG, M.D., *Curator and Junior Associate in Anatomy at The Wistar Institute.*

No systematic study of the growth of any mammal after castration has yet been reported. The existing literature on castration deals mainly with its application to domestic animals for economic purposes. There are, however, some general descriptions and measurements made during life on human castrates; Matignon ('96), Pelikan ('76) and Jameson ('77), also several reports of dissections of eunuchs; Ecker ('64-'65), Gruber ('47), Lortet ('96), Becker ('99), Tandler and Grosz ('09), together with a considerable number of investigations on animals showing the dependence of the secondary sexual characters on the integrity of the testes; Ribbert ('98), Rörig ('99, '99A, '01), Sellheim ('98) and Foges ('02).

Further we have some literature, based on animal experiments, touching the interdependence of the hypophysis and of the thyroid gland on the testes: Fichera ('05, '05A), Richon and Jeandelize ('05, '05A).

In chickens, rabbits and dogs studies have been made on the growth of parts of the skeleton, especially the growth of the limb bones which become longer than normal: Poucet ('78), Richon and Jeandelize ('05B, '05C), Sellheim ('99).

Finally, McCrudden ('08) has studied the metabolism of castrated dogs, using the excretion of salts as an index. These experiments show the operation to be without any marked influence on metabolism in this animal.

The chief result of the experimental work is, therefore, to show that many secondary characters in mammals and birds are modified in their development by injury or removal of the testes, and that the latter probably produce their effect through some form of internal secretion, as shown by the observations of Walker ('08). The growth of parts of the skeleton and some of the ductless glands are also in a measure and in some animals affected by castration.

In the present communication, however, we shall consider the influence of castration only in relation to the increase in body

weight with age, making incidentally one application of the results to the phenomenon of prepubertal growth in man.

The observations to be presented were made on the albino rat (*mus norvegicus* var. *albus*) and are arranged in three series; one made for Dr. Donaldson in the Neurological Laboratory of the University of Chicago by Dr. S. W. Ranson in 1905-6, and the others by myself at The Wistar Institute in 1907 and 1908.

The comparison in growth was made always between members of the same litter, some of which were castrated, while the others were left intact to serve as controls. All the members of one litter were reared together in the same cage and fed similarly. The diet was ample and varied and included milk, except in series two.

The operation proved to be simple, and was performed on the fourteenth or fifteenth day after birth, at which time the sexes can be easily distinguished.

The males of the litter were removed from the nest and weighed to determine whether they were of normal weight. Each one was then marked upon the pinna of one or both ears. Those selected for controls were returned to the nest, while those assigned for operation were placed in warm cotton. For operation the animal was anæsthetized and the operation conducted under antiseptic precautions:—

The incision was made in the mid-line of the perineum and each testis drawn forward and its connections severed. The wound was washed with bichloride and dressed without stitches with thin celloidin. No case of infection of the wound occurred, and all the operations were successful.

All traces of blood or its odor must be removed before the rat is returned to the nest, otherwise the mother is apt to kill it.

In returning the operated rats to the nest, the mother was first removed and kept away until the operated animals had become satisfied to remain with the balance of the litter and had acquired the odor and warmth of the nest.

The mother was then allowed to enter and was not disturbed for twenty-four hours, after which time it was found there was not much danger that the young would be destroyed by her.

The weight record was taken at regular intervals, increasing

from daily records to those taken once a week. The rats were disturbed as little as possible in the process, the cage always being taken to the balance table, the rat gently placed in a perforated tin box (balanced by a counterweight) and weighed as quickly as possible, and the record set down opposite the record of the distinguishing ear-mark.

It was found best not to attempt to weigh the rats immediately after any unusual excitement in the colony-room, as under such conditions they show a temporary loss of weight; even the presence of strangers may cause them to become unusually restless and easily frightened.

The weighing was continued as long as the animals remained in a healthy condition, and the weights of a litter maintained a comparative uniformity.

During the period between 150 and 200 days, the albino rat is subject to numerous affections which disturb its growth, so it was found impracticable to follow more than a few litters beyond 200 days.

The data for these records are based on 99 animals, of which 52 were castrated and 47 were controls. These fall into three series.

While the observation of no one series was continued during an entire year, the combined records include the 12 months, so that any pronounced seasonal influence, if present, could be noted. No indication of such influence has thus far been observed.

In series No. 1, the records for which were made by Dr. S. W. Ranson at the University of Chicago during the summer and fall of 1905, continuing into the spring of 1906, there were ten litters numbering 40 animals, of which 21 were castrated and 19 were controls. The constitution of the series was the following:

Litter	Number of castrated.	Number of controls.
1	3	3
2	2	2
3	3	3
4	1	1
5	2	2
6	2	1
7	4	4
8	2	1
9	1	1
10	1	1

In series No. 2, the records for which were made at The Wistar Institute, Philadelphia, during the summer and fall of 1907, there were 8 litters numbering 27 animals, of which 14 were castrated and 13 were controls. The constitution of the series was the following:

Litter	Number of castrated.	Number of controls.
1	1	1
2	2	2
3	1	1
4	2	1
5	3	3
6	1	1
7	1	1
8	3	3

In series No. 3, the records for which were made at The Wistar Institute during the winter, spring and summer of 1908, there were 9 litters numbering 32 animals, of which 17 were castrated and 15 were controls. The constitution of the series was as follows:

Litter	Number of castrated.	Number of controls.
9	3	2
10	2	2
11	1	1
12	1	1
13	2	2
14	2	2
15	3	2
16	1	1
17	2	1

It will be impracticable to give the records for all the litters in each series, but to show how the two groups in each litter change during growth, three examples will be given as represented by litters 2, 4 and 5 of Series 2. The tabulated results are not given, but the curves based on them are shown in Figure 1.

These three records serve to illustrate what took place in all the series, *i. e.*, in some litters the castrated grew faster, in some the con-

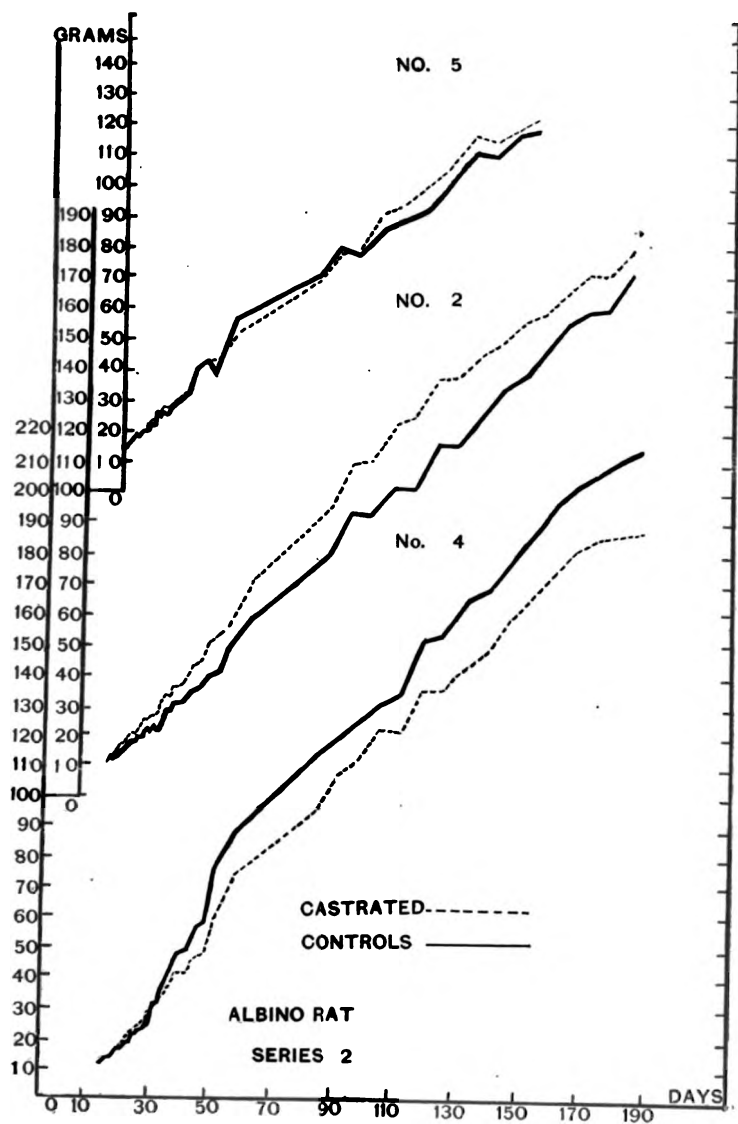


FIG. 1

trols, and in others the two curves were nearly identical. The immediate effect of the operation on growth was not detectable. A review of all the litters shows that the castrated surpass the controls about as often as they fall below them.

Moreover in a given litter the incidental variations in the two groups tend to coincide, showing that the castrated rats are just as

TABLE 1.

Showing for Series 1 the body weight based on the average of the litters at different stages. In the fifth column are given the numbers of the litters on which the averages are based, and in the sixth column the number of the litters permanently removed.

Average Age. Days.	BODY WEIGHT IN GMS.		Number of Individuals.	LITTERS.	
	Castrates.	Controls.		Used for Averages.	Permanently Removed.
16	17.6	17.8	15	1-10.	
20	21.4	22.0	20	1-10.	
27	27.2	27.9	20	1-10.	
27	32.5	32.7	20	1-10.	
31	42.0	37.4	10	1-10.	
33	40.6	40.7	10	1-10.	
36	43.5	43.9	10	1-10.	
39	46.8	47.2	10	1-10.	
42	48.2	51.7	9	1-3, 5-10	
45	52.5	56.7	9	1-3, 5-10	
48	58.2	60.9	9	1-3, 5-10	
51	63.0	67.1	8	1-4, 6-8, 10	
54	68.8	70.5	10	1-10.	
57	78.9	77.7	8	1-7, 9, 10.	
60	78.0	79.5	10	1-10.	
63	84.8	79.9	8	1-7, 9.	
66	95.2	93.8	8	1-8.	
74	102.8	101.8	12	1-9.	
78	108.0	103.7	9	1-7, 10	
83	116.3	116.9	12	1-9.	
87	122.4	123.1	10	1-8, 10	
93	130.6	130.0	9	2-7, 9.	
99	137.9	141.2	11	1-10.	
106	148.8	144.7	10	1-7.	
116	151.7	147.8	4	1, 4, 5, 10.	
125	157.0	165.3	9	1, 4, 6-8.	
134	165.8	174.6	7	1, 2, 4, 7, 10.	
143	179.9	191.4	5	1, 4, 8.	5, 7, 10.

susceptible as are the controls, to the minor influences modifying growth. See Figure 1.

To determine the general relations of the two curves when all of the litters of a given series are taken together, the following method was used:

The average weights of the individuals in each group of each litter was determined at the time of each weighing.

These averages were tabulated according to age in days.

The results were then averaged for all of the litters in the series and again tabulated according to age in days.

Since different litters vary widely in their growth, it seemed best in the final averages just mentioned to take the average for each

TABLE 2.

Showing for Series 2 the body weight based on the averages of the litters at different ages. In the fifth column are given the numbers of the litters on which the averages are based, and in the sixth column the number of the litters permanently removed.

Average Age. Days.	BODY WEIGHT IN GMS.		Number of Individuals.	LITTERS.	
	Castrates.	Controls.		Used for Averages.	Permanently Removed.
16	15.5	15.2	12	1-8.	
18	16.7	16.6	16	1-8.	
20	18.4	18.3	16	1-8.	
22	20.6	20.3	16	1-8.	
24	22.9	22.4	16	1-8.	
26	25.0	24.6	16	1-8.	
28	26.6	26.5	16	1-8.	
30	28.8	28.5	14	1-8.	
32	30.6	31.2	14	1-8.	
34	31.4	32.7	12	1-6.	
36	35.1	36.5	11	1-5, 7, 8.	
38	42.9	43.6	7	1, 2, 5-8.	
40	43.2	44.9	7	1-4, 6.	
42	45.3	48.3	6	1, 3-5, 7, 8.	
44	54.2	56.4	5	1, 2, 5-7.	
46	44.9	45.0	4	2-4, 6.	
48	48.6	52.9	5	1, 3-5, 8.	
50	60.6	62.0	4	1, 2, 5, 6.	
52	60.7	63.5	4	2, 3, 4, 7.	
55	69.4	77.8	5	1, 2, 5, 6.	
66	76.3	78.5	5	1-4, 8.	
80	94.6	92.6	4	5-8.	
87	99.9	102.0	8	2, 3, 5-8.	
94	106.7	107.5	8	2-8.	
101	110.8	112.0	8	1-8.	
108	119.0	118.0	8	1-8.	
115	122.4	121.8	8	1-8.	
122	129.0	126.0	7	2-8.	1.
130	131.9	133.3	10	2-8.	
137	140.4	140.6	5	2, 4-7.	
144	143.5	144.6	5	2, 4-7.	3, 8.
151	149.1	149.4	5	2, 4-7.	
159	156.6	160.3	6	2, 4-7.	
166	166.8	166.7	4	2, 4, 6, 7.	
174	175.3	170.5	4	2, 4, 6.	7.
185	182.6	190.7	4	2, 4.	6.

litter as a unit, and not to weight it by the number of individuals in the litter. The averages of the observations are made at short intervals for the first fifty or sixty days, and then at longer intervals to the end of the series.

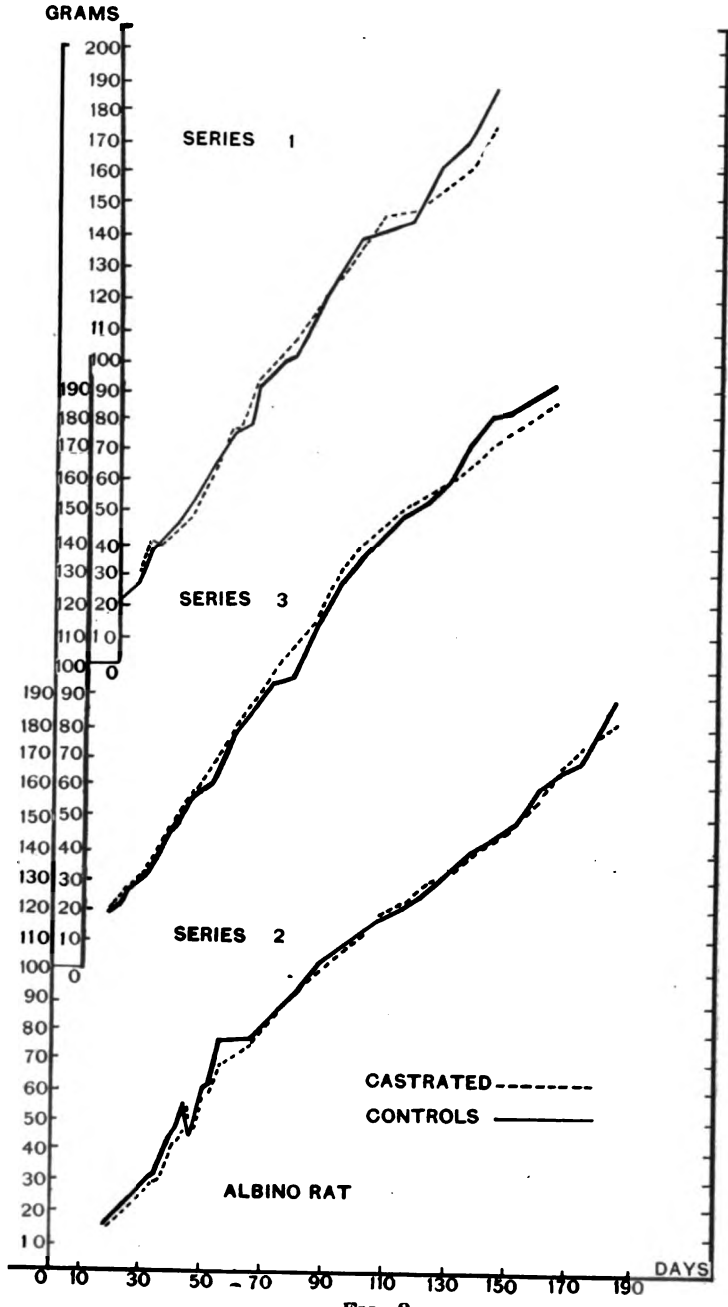


FIG. 2.

The results thus obtained are given in tables 1, 2 and 3 and in Figure 2. In explanation of tables 1, 2 and 3, the following comments are in place.

In the age groupings used, not all the litters are represented every time. This of course tends to alter the direction of the curves, but does not modify the value of the comparison between the castrates

TABLE 3.

Showing for Series 3 the body weight based on the averages of the litters at different ages. In the fifth column are given the numbers of the litters on which the averages are based, and in the sixth column the numbers of the litters permanently removed.

Average Age. Days.	BODY WEIGHT IN GMS.		Number of Individuals.	LITTERS.	
	Castrates.	Controls.		Used for Averages.	Permanently Removed.
18	18.9	18.9	8	9-16.	
21	22.0	21.4	8	9-14, 16, 17.	
23					
25	25.9	26.1	8	9-15, 17.	
28	29.2	28.5	8	9-14, 16, 17.	
30					
32	33.5	32.3	7	9-14, 17.	
35	41.3	38.9	8	9-14, 16, 17.	
38	45.4	44.7	7	9-14, 16, 17.	
42	50.4	49.8	9	9-17.	
45	56.0	56.4	9	9-17.	
49	60.3	59.4	9	9-17.	
52	67.2	65.5	9	9-17.	
56	72.4	71.0	9	9-17.	
60	78.3	76.5	9	9-17.	
63	82.4	80.9	9	9-17.	
67	88.3	86.3	9	9-17.	
72	97.2	94.0	16	9-17.	
79	107.0	102.5	11	9-17.	
86	114.8	113.4	10	9-17.	
93	129.0	125.3	9	9-17.	
100	140.0	135.3	9	9-17.	
107	146.4	143.4	9	9-17.	
114	153.2	150.1	9	9-17.	
121	157.2	155.0	8	9-17.	
128	161.3	159.2	9	9-17.	
135	168.5	174.3	8	9-11, 13-17.	12.
142	177.0	182.7	7	9-11, 14-17.	13.
149	181.5	183.5	7	9-11, 14-17.	
156	184.1	187.6	7	9-11, 14-17.	17.
164	189.6	190.3	9	9-11, 14-16.	
172	188.7	198.3	6	9-11, 15, 16.	
181	195.2	202.4	6	9-11, 14-16.	

and controls. A notable instance of this occurs at 46 days in Series 2. See Table 2 and Figure 2. In column 5 of the tables, the litters involved in each average are indicated by their numbers.

Moreover, towards the end of the series, observations on some litters ceased earlier than on others, and the effect on the curve is simi-

lar to that described above, with the additional effect of permanently reducing the number of cases and hence the general significance of the averages.

Observation in the case of any litter was usually brought to a close by some illness which interfered with the normal growth of one or more of the animals.

In such a case, observations on that litter were discontinued. When this occurred, the fact is noted in the last column of each table.

CONCLUSIONS.

1. In the case of albino rats, the growth curve for the castrates is similar to that for the normals.
2. Castrates are as susceptible as normals to the incidental influences modifying growth.
3. Castrates are as susceptible as normals to the forms of disease and digestive disturbances which hinder normal growth.

Although these observations show that in the albino rat the normal growth curve is not modified by castration, yet it is not uncommonly assumed that in man prepubertal growth is casually related to the maturing of the reproductive system at puberty.

Against this assumption, in addition to the direct evidence furnished by the foregoing observations, the following facts may be adduced:

In man castration is not usually practised before the ninth year (Möbius, '96). Castrates are never described as dwarfed, and are often stated to be heavier (*i. e.*, fatter) or to have longer limb bones than normal (Ecker, '64, '65), (Lortet, '96), (Tandler and Grosz, '98).

The amount of growth is then certainly not diminished, and it seems probable therefore that prepubertal growth is not retarded by castration. Indeed there are positive statements in the literature to the effect that it is increased.

Further in support of the idea that the relation between puberty and prepubertal growth in man is merely incidental, we have the fact that in the rat the corresponding point in the growth curve,

where the females are heavier than the males, comes to end at 50 days, while puberty does not occur until about 70 days (Donaldson, '06) and in the guinea-pig the corresponding period comes to an end at 19 to 31 days and puberty is not attained until 150 days (Minot, '91).

It seems highly probable therefore that puberty in man is not a factor in stimulating prepubertal growth.

It is desirable to emphasize in closing that these conclusions are not to be interpreted as invalidating the view, which rests on good experimental evidence, that the full development of secondary sexual characters in some birds and mammals at least, is dependent on the integrity of the testes which act directly or indirectly through some form of internal secretion.

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A COMPARISON OF THE ALBINO WITH THE GREY RATS IN RESPECT TO THE WEIGHT OF THE BRAIN AND SPINAL CORD. By S. HATAI, *The Wistar Institute of Anatomy.*

A comparison of the brain and spinal cord weights in the grey rat with those in the albino rat shows that the former has a much heavier central nervous system than the latter. The difference is considerably greater in the brain, than in the spinal cord weight. In the case of the brain weight, the difference appears at an earlier period of life (little over ten days after birth), while in the case of the spinal cord weight it does not appear distinctly until the body weight becomes about 180 grams, that is at the time when the body length in the grey rat becomes greater than in the albino rat. So far as the weight of the brain is concerned, the present investigation confirms the observations of Darwin and of Lapicque that the brain weight is proportionately smaller in the domesticated than in the wild race from which it is derived. The explanation suggested by Darwin, that this may be due to the effect of disuse, seems inadequate.

ON THE RELATION OF THE BODY LENGTH TO THE BODY WEIGHT AND TO THE WEIGHT OF THE BRAIN AND OF THE SPINAL CORD IN THE ALBINO RAT (*MUS NORVEGICUS* VAR. *ALBUS*). HENRY H. DONALDSON, *The Wistar Institute, Philadelphia.*

It was the purpose of this investigation to obtain primarily a linear measure of growth in the albino rat. This being obtained, it would be possible first to get for this form the ratio obtained by dividing the body length by the body weight; second, to relate the weight of the brain and of the spinal cord to the body length and, finally, to compare the growth in body length in the rat with the corresponding growth in sitting height in man. For the mathematical treatment of the results, I am indebted to my colleague Dr. Hatai.

The body length was measured from the tip of the nose to the root of the tail (on the ventral side), the animal lying relaxed on

its side. When the data are arranged in groups differing by 10 grams in body weight and 10 mm. in body length, the coefficient of correlation between body weight and body length is found to be .90.

For a given body weight the male has a slightly greater body length. This explains the slightly greater weight of the central nervous system in the male.

When the data are arranged in groups differing by 10 mm. in body length and 0.1 grams in brain weight, the coefficient of correlation is found to be .86.

When the data are arranged in groups differing by 10 mm. in body weight and 0.04 grams in spinal cord weight, the coefficient of correlation is very high, being .99.

The curve for the increase in the weight of the spinal cord, according to stature, is a straight line. This departure from the usual form of the growth curve is largely due to the passive elongation of the cord in response to the lengthening of the vertebral column. Body length is the best datum thus far found from which to infer the weight of the brain or of the spinal cord.

The body length in the rat corresponds with the sitting height in man and during active growth both increase in nearly the same proportion, indicating that in both forms the spinal cord is subject to a similar amount of passive lengthening.

A MODERN METHOD OF TEACHING THE ANATOMY OF THE BRAIN.

By H. J. H. HOEVE, M.D., *Professor of Anatomy in Drake University, Des Moines, Iowa.*

In a recent number of the ANATOMICAL RECORD (Vol. 2, No. 8) Professor Johnston described a method of brain dissection showing the architecture of that organ more effectively than is possible with the methods ordinarily used. My method (which was in part demonstrated at the last meeting of the Association of American Anatomists) is designed for a similar purpose, but differs considerably in the manner and order of procedure. It is here presented, as fully as the limited space will permit, in the hope that it may be of service to those interested in the teaching of this difficult subject.

The different steps in the technique of the removal of the brain are well known, but there are a few points which seem to me of great value. After the tentorium cerebelli is cut and the lower part of the medulla also, and the brain ready to be delivered, I cut transversely across the sinus occipitalis, that is just inferior to the confluens sinuum, in order that the falx cerebri and the tentorium cerebelli may remain attached to the brain without being loosened. I ligate the anterior end of the sinus sagittalis superior, the distal end of the sinus occipitalis and the cut ends of the sinus laterales. The falx and the tentorium are left in place on account of the desirability of preventing the rupture of the Vv. magnae (*galeni*) and the Vv. cerebri superiores; and the ligation of the cut extremities of the sinuses is to prevent the outflow of venous blood. The importance of these two steps is readily appreciated if we remember that the gray matter of the brain is of a much darker color in those brains where the venous blood is retained. The color of the gray matter depends first upon its own pigment and second upon the amount of blood contained.

After having experimented with brains macerated in dilute nitric, hydrochloric and acetic acid, alcohol, frozen, boiled in oil and some slowly hardened in alcohol, etc., I find no chemicals which will harden the brain in such a way that its fibres can easily be dissected. Fixing the brain in formalin and then hardening it in alcohol has its good points. Formalin and glycerine give pretty fair results,

but it takes too much time. For these reasons I believe that for general purposes the fresh brain should be hardened in formalin. Put the brain in a 1 per cent. solution and change the second day to a 2 per cent. solution. Change this every day until the brain is hardened, and then increase the strength gradually up to 5 per cent. in which the specimen can be kept indefinitely. The brains of bodies injected with zinc chloride are not as good for our purposes as those injected with formalin, carbolic acid and glycerin. The brain must be hardened slowly, and that can readily be accomplished by using the weaker solutions of formalin. If the brain is put at the beginning in a 5 per cent. solution of formalin, then frequently the outside hardens to the depth of about an inch and the inside will remain soft, at least too soft to be fit for the fibre dissection.

For Instruments Used for Fibre Dissection, I have never found anything as handy as a small stick of orangewood (which comes in manicure sets), the point of which is flattened, and the heavy extremity left as it is. With this instrument the fibres of the brain can be elevated nicely and rolled out of their respective positions, which is not possible with the handle of the scalpel, forceps or the toothpick. The heavy end of the stick can be used to elevate larger parts of tissue, especially for the removal of small association fibres, which extend from one gyrus into another by curving around the bottom of the sulci. A pair of forceps is used for the removal of the pia and of small pieces of tissue.

The method of dissection which I follow consists of breaking, teasing and cutting the brain tissue. As soon as fibres are exposed, the orangewood stick is used, which seems to be just hard enough to handle the fibres nicely without cutting or tearing them. (Metal will break every fibre which it touches.) After a small bundle of fibres is loosened carefully it is taken hold of with the fingers if possible and the point of the stick put behind it in such a way as not to touch the fibres beneath it, and then the fibres are carefully and slowly removed parallel to the direction of the bundle to which they belong. All the association bundles can readily be dissected in this fashion.

Space will not permit to give a complete outline, but I will attempt to give a general idea of the order of dissection. After having dis-

sected a good many brains according to the method of F. J. Gall and J. G. Spurzheim (1834) following the fibres from below upward into the brain, I came to the conclusion that the association bundles were destroyed in every case, and that a good many other structures were also damaged by that method. So after making several attempts to save them, I concluded that it would be better to dissect them first, and that is my reason for starting the dissection at the upper part of the cerebrum.

The students dissect first the *dura mater encephali*, the *processus durae matris*, the *sinus durae matris*, the *emissaria* and the *cavum subdurale encephali*. Then comes the *arachnoidea encephali* and the *granulationes arachnoideales*, the *cavum subarachnoideale* and the *pia mater encephali*. Next all the arteries of the brain are exposed. The venous systems of the brain are next followed out in detail. Study and remove the *pia*, *falx cerebri* and *tentorium*. Remove the cerebrum by a cross section just above the midbrain. Then separate the cerebral hemispheres by a sagittal section through the *corpus callosum*. Study the external surface of the cerebral hemisphere, including successively the lobes, *gyri* and *sulci*, the *Bulbus olfactorius*, *Tractus olfactorius*, *Trigonum olfactorium*, *Area parolfactoria*, *Substantia perforata anterior*, *Chiasma opticum*, *Tractus opticus*, *Lamina cineria*, *Tuber cinerium*, *Hypophysis cerebri*, *Corpora mammillaria*, *Substantia perforata posterior*.

Make a horizontal incision one-half inch deep on the mesial surface of the hemisphere one-half inch above the *dorsum corporis callosi*. Insert the fingertips into the incision and tear the cortex above it upward and outward. Look for fibres of the *fasc. occipito-frontalis* running in an antero-posterior direction. Gently remove the cortex from the *gyrus cinguli*, the *gyrus hippocampi* and the *uncus*, and find the fibres forming the *cingulum*.

Fasc. Occipito-Frontalis (Foreli).—The horizontal fibres which became exposed when the upper part of the hemisphere was removed are found most easily at a point one-half inch external to the junction of the middle with the posterior one-third of the *corpus callosum* and can be followed backward, downward and inward (*Tapetum*).

Fasc. Perpendicularis (Wernicke).—Break the *gyri* of the external surface of the *lobus occipitalis* and find perpendicular fibres,

three-fourths inch internal to its external surface and one inch anterior to the *polus occipitalis*.

Fasc. Longitudinalis Inferior.—Develop and expose the fibres of the *Fasc. longitudinalis inferior* by boldly following them forward and backward to where it interlaces with the posterior end of the *fasc. long. sup.*, and the lower end of the *Fasc. perpendicularis*.

Fasc. Uncinatus.—Scrape carefully through the gray matter of the insula and find fibres which extend from before backward and downward external to the *claustrum*. The lower ones form an arch (*Fasc. uncinatus*).

Next in order come the *Corpus Callosum*, *Ventriculus Lateralis*, *Septum Pellucidum*, *Cavum Septi Pellucidi* and *Fornix*. Make an antero-posterior incision through the *corpus callosum* one-fourth inch lateral to its cut margin and, inserting the fingertips, lift the white brain substance external to the incision upward and outward, in order to expose the *ventriculus lateralis*. Remove the outer wall of the *cornu inferius et posterius ventriculi lateralis*. Cut the *corpus callosum* transversely and remove it. Follow the *columna fornicis* downward and find its *fasciculus olfactorius* as it passes over the *commissura anterior*. Cut transversely through the *corpus fornicis*, one-fourth inch posterior to the *foramen interventriculare* (*Monroi*) and dissect it backward. Study the *Commissura Hippocampi*, *Verga's Ventricle*, *Tela Chorioidea Ventriculi Tertii*, *Ventriculus Tertius*. Find the *commissura anterior* and then follow the *columna fornicis* from below upward until the *commissura* is reached. Scrape the *commissural* fibres and follow them clear back into the *lobus occipitalis*, where they interlace with the fibres of the *fasc. long. inf.* and the *cingulum*.

Study the following structures: *Thalamus*, *Nucleus Hypothalamicus* (*Luysi*) *Commissura Anterior*, *Clastrum*, *Nucleus Amygdalae*, *Capsula Interna*, *Corpus Striatum*, *Nucleus Lentiformis*, *Nucleus Caudatus*. Break the cortical and white matter above the insula, from without upward and inward and expose the entire insula. Remove the insula, the upper part of the *fasc. uncinatus*, the *claustrum* and the *capsula externa*, and expose by gentle scraping the external surface of the *nucleus lentiformis*. Find the antero-inferior fibres of the *pars frontalis laminae superioris capsulae in-*

ternae projecting forward, just between the antero-superior parts of the nucleus lentiformis and the caput nuclei caudati. By scraping through them, find the two bodies communicating just inferior to them. Carefully remove the fibres of the capsula interna from between the two bodies and expose the outer surface of the thalamus, but do not injure the cauda nuclei caudati.

Study the *Stria Terminalis*, *Massa Intermedia*, *Commissura Posterior*, *Corpus Pineale*, *Corpus Geniculatum Laterale*, *Corpus Geniculatum Mediale*. Find the taenia terminalis by removing the vena terminalis and follow it downward toward the foramen interventriculare (*Monroi*). Flap the tractus opticus outward after detaching it. Push the corresponding columna fornicis over to the opposite side and follow the taenia downward to just above the commissura anterior. Find that just external to the columna, above the commissura anterior, and inferior to the foramen interventriculare, it divides into two fasciculi, which should be carefully followed according to the direction of their fibres.

Next proceed to the *Mesencephalon*, *Pedunculi Cerebri*, *Substantia Nigra*, *Tegmentum*, *Pons*, *Medulla* and *Cerebellum*. Scrape the fibres away from the midbrain, and expose the substantia nigra. Find that the latter is surrounded by fillet fibres. Expose the nucleus ruber tegmenti and its peculiar relations. Remove the pia and vessels carefully from the entire cerebellum. Make a median sagittal section through the vermis from behind forward and bend the two lobes carefully outward without detaching them. Study the sulci and laminae of the vermis. Examine the ventriculus quartus. Identify the decussatio pyramidum. Separate the lateral halves of the pons and medulla, by a midsagittal section. Remove all the cortical matter from the hemisphaerium cerebelli.

Brachium Pontis.—Remove the laminae of white matter from the superior surface of the brachium pontis. Remove the tonsilla and the rest of the small leaflets from the inferior surface of the brachium pontis and find the fibres of the Fasc. obliquus separated from the corpus restiforme by the Fasc. transversus pontis. Remove about one-fourth of the Fasc. obliquus pontis, just external to the superficial origin of the nerv. trigeminus, in order to expose the Fasc. transversus fully. Find that the fibres of the Fasc. transversus pontis

form the greater part of the vermis superior. Find that by communicating with its fellow of the opposite side it forms a complete ring around the upper two-thirds of the ventriculus quartus. Within this ring are found from behind forward, the fibres of the corpus restiforme, the corpus dentatum, and the fibres of the brachium conjunctivum.

Brachium Conjunctivum.—Remove the ventricular lining from the internal surface of the brachium conjunctivum and follow its fibres carefully downward and backward, exposing at the same time the corpus dentatum.

Corpus Restiforme.—Follow the fibres of the corpus restiforme by cutting through the brachium conj. just anterior to the hilus corporis dentati. Expose the entire corpus dentatum. Cut through the corpus, just anterior to the tail of the corpus dentatum, and also sever the Fasc. transv. pontis and the brachium conj. at the same level, in order to proceed with the dissection of the pons and medulla.

Nervus Trigeminus.—Remove carefully the part of the Fasc. obliq. pontis above the nerv. trigeminus and follow the latter horizontally backward and inward. Bend the brachium conj. carefully outward and upward and follow the radix descendens nervi trigemini upward.

The Fasciculi Longitudinales Pontis.—Remove some of the fibrae pontis superficiales and notice that longitudinal fibres (Fasciculi longitudinales pyramidales pontis) pass through the fibrae pontis profundae. Trace the fasciculi longitudinales downward and find that they form the pyramis medullae. Cut the Fasc. long. at the lower border of the pons, and carefully reflect the pyramis medullae forward and downward. This will expose the fibres of the fasc. cerebro-spinalis lateralis and those of the fasc. cerebro-spinalis anterior; and at the same time the decussatio pyramidum. Find the small masses of gray matter (Nuclei pontis). Cut the fasc. cerebro-spinalis lateralis close to the median line (decussatio pyramidum) at right angles to the direction of its fibres.

Lemniscus System.—Trace the lemniscus lateralis downward and forward by removing the fibrae pontis profundae. After the fasciculi longitudinales are removed, a thin layer of transverse fibres (Cor-

pus trapezoideum), from which the longitudinal fibres readily separate presents itself. Find that the lemniscus lateralis is continuous with a broad sheet of fibres (Lemniscus medialis) which extends upward in the same plane. Remove all the fibrae pontis profundae and find the lemniscus medialis. A thin strand of fibres (Lemniscus superior) lies anterior to the lemniscus lateralis, at the upper border of the pons. Find that the lower end of the lemniscus can easily be followed downward to a point where it assists in forming the lemniscus interolivaris. Scrape carefully just anterior to the lemniscus lateralis, on the outer side of the brachium conjunctivum, and expose the fibres which correspond to the lemniscus superior. Find that the lemniscus interolivaris consists partly of the fibres extending between the two olivae and find that it consists of a crossing of fibres which can be traced backward, downward and a little outward to the gracile and cuneate nuclei. Find that the fibres which arise on one side in the gracile and cuneate nuclei are continued upward on the opposite side in the lemnisci medialis, lateralis et superior. Follow the anterior external arciform fibres backward over the oliva into the corpus resiniforme. Find that some longitudinal fibres (Lamina superficialis fasciculi proprii lateralis) cover the oliva. Find the longitudinal fibres (Lamina profunda fasciculi proprii lateralis) postero-internal to the oliva. Find longitudinal fibres (Fasc. antero-lateralis superficialis descendens) internal to the sulcus lateralis anterior. Find longitudinal fibres external to the oliva (Lamina superficialis fasciculi proprii antero-lateralis) and follow them downward to just below the oliva. There they join the longitudinal fibres which lie internal to the oliva (Lamina profunda fasciculi proprii antero-lateralis) and form the fasciculus proprius anterolateralis. Follow the fasc. cerebello-spinalis upward from the point where it crosses the sulcus lateralis posterior to the posterior surface of the medulla.

The advantages of this method may be given as follows: The students can accomplish more in less time. They obtain better ideas of the macroscopical structures of the brain. All that can be seen in slices can be worked out by fibre dissection. In reality there is not one structure in the brain which can be displayed to its fullest advantage by any other method.

ON THE EMBRYOLOGY OF THE CORPUS PONTO-BULBARE AND ITS
RELATION TO THE DEVELOPMENT OF THE PONS. By CHARLES
R. ESSICK. *From the Anatomical Laboratory, Johns Hopkins University.*

The study of the embryology of the Corpus Ponto-bulbare throws considerable light on the adult body which I described for the human hind-brain.¹ In the adult was found a mass of cells and fibres normally present in all brains but showing considerable variations in its size and development. It was described as arising more or less indefinitely from the transverse fibres of the pons mesial to the fifth nerve and gathering into a well-defined bundle which curved into the long axis of the brain behind this nerve and then passed between the seventh and eighth cranial nerves. It continued backward with a dorsal curve, encircling the dorsal cochlear nucleus, and usually ending as a free tip projecting into the roof of the fourth ventricle. The study of its origin shows it to begin at the caudal end and extend cephalad, hence the embryonic description must be reversed. Whereas the mature body varies so greatly in development, often differing on the two sides of the same brain, the embryonic counterpart is remarkably constant. In addition it must be kept in mind that the ponto-bulbar body is present before any pontine formation occurs, appearing first as a thickening in the secondary "Rautenlippe" of His, just behind the dorsal cochlear nucleus. Later the cells migrate over the restiform body and advance to the pontine flexure between the facial and acoustic nerves.

The fact that in the adult this structure varies in amount of development; the fact that in the embryo it is so constant; and finally the fact that at first it is so large when compared to the pons, at once suggests that we are dealing with something which possesses more function in the embryo than in the adult. This study demonstrates that its function is to furnish a path by which cells, arising at the lateral margins of the medulla, wander to the ventral surface of the brain and form the main mass of pontine nuclei.

In the 20 mm. embryo of the Mall Collection (No. 22) immediately

¹C. R. Essick, The Corpus Ponto-bulbare, a hitherto undescribed Nucleus in the Human Hind-brain. *Amer. Jour. Anat.*, vol. vii, p. 119.

caudad to the dorsal cochlear nucleus, appears a circumscribed thickening of the secondary "Rautenlippe" in which an active division of cells can be made out. This is the point of origin for the pontine cells which travel down the path described for the corpus pontobulbare.

In the 23 mm. embryo (No. 382), the ventricular margin just behind the dorsal cochlear nucleus is rich in mitotic figures, and here due to the active proliferation of cells, the "Rautenlippe" is markedly thickened. From this point as a starting place deeply-staining elongated nuclei extend laterally around the restiform body and pass forward between the facial and acoustic nerves as far as the trigeminal nerve. The sheet of nuclei has become much thinned out in its cerebral portion, so that the layer is only one to two cells thick at the fifth nerve, and the same condition obtains for its mesial border, which is rapidly lost after the sagittal plane of the emergent facial is passed. The distribution of mitotic figures is striking. Numerous karyokinetic figures appear in every section around the central canal, but as soon as this is left, only an occasional dividing cell is made out and the difficulty in finding them increases the farther cephalad one passes in sections. Clearly then we are dealing not with a growth by extension but an actual migration of cells. This embryo has no pons.

In the 28 mm. embryo (No. 75), the active formation of cells still continues in the domain of the "Rautenlippe" caudal to the dorsal cochlear nucleus and the entire body is much thickened. Cephalad it can now be traced almost to the mid-line on both sides, arching over to the pontine flexure from the lateral portions and presenting an advancing edge of only one or two cells in thickness.

In the 30 mm. embryo (No. 45), the cells of both sides have met and fused across the mid-line directly over the pontine flexure and the primitive anlage of the pons is formed. In the older embryos the addition of cells continues so that there is a heaping up of cells over the mid-line forming the well known crescentic shape which the pons gives in cross-section.

The course of the cells, in sections, is not difficult to follow because of their peculiar affinity for stains, a characteristic of all

young nuclei, and this property gives a brilliant differentiation of the ponto-bulbar body from the structures with which it comes into close contact. With the exception of the deeply colored lining which surrounds the ventricular cavity, the ponto-bulbar body is the most striking part of sections through this portion of the embryonic medulla and many authors have given good illustrations of the corpus ponto-bulbare, noting its connection with the "Rautenlippe" as well as its extension to the ventral surface of the brain. There has been a failure to connect it with the development of the pons.

This study was greatly aided by sections and dissections of other mammalian embryos where absolutely fresh material is available. This comparative work has simply confirmed the above findings.

A migration of cells from the dorso-lateral margin of the medulla to the ventral portion of the brain has been described by His² for the complex which he designates "die zerrissenen Kerne." To these belong the olives and their neighboring structures. "All of their cells abandon the place where they were originally formed and press through to the mesial lying regions of the medulla. * * * As far as the cells are concerned these structures are, therefore, descendants of the alar plate and morphologically arise from the same longitudinal zone of the medullary tube from which come the higher-lying parts of the brain, *i. e.*, the cerebellum, quadrigeminal bodies, geniculate bodies and the cerebral hemispheres." In the concluding sentence of his classical treatise on the development of the Rhomboid Brain, he mentions his intention to take up the development of the pons and cerebellum and believes that the real key to the development of the former, the pons, will be furnished by the principle of lamina formation. It seems very plausible that this very principle has been observed in the sheet of nuclei arising in the "Rautenlippe" behind the dorsal cochlear nucleus and after encircling the brain for almost 180°, the cells come to rest on the ventral surface of the Rhomboid Brain and later send their processes laterally to form the middle peduncle of the cerebellum. The corpus ponto-bulbare in the fully developed brain represents those

²W. His, Die Entwickl. des Mensch. Raut., 1891.

cells with their processes which have not descended to the pons, but lie scattered along the channel where in embryonic life an active migration of cells took place from the "Rautenlippe" of the fourth ventricle to the pontine flexure.

THE NERVUS TERMINALIS IN TELEOSTS. By R. E. SHELDON, *The University of Chicago*, and CHAS. BROOKOVER, *Buchtel College*.

Recently, in some preparations of the olfactory apparatus of the carp (*Cyprinus carpio*), prepared at the Ohio State University Lake Laboratory at Sandusky by Mr. T. S. Jackson, some three hundred ganglionic cells were observed along a separate and distinct strand of the olfactory nerve. This condition was noted in an adult individual about twenty-five centimeters long. The cells are somewhat larger than the sheath cells of the olfactory fibers, with the Nissl granules appearing rather indistinct. They are situated on the ventro-median side of the nerve about half way between the olfactory bulb and the olfactory capsule. Cells can be traced, however, caudad to the glomerular region of the bulb, the formatio bulbaris, and rostrad nearly to the capsules. The cells diminish in number rapidly as one passes caudad or rostrad from the main group of ganglionic cells. It should be noted that these cells correspond in position and appearance to those described in the ganglion of the nervus terminalis (nerve of Pinkus) in *Amia* by Brookover.¹ Coarse fibers similar to those in *Amia* can be traced from the ventro-median side of the bulb rostrad to the olfactory mucous membrane where they are distributed to all parts of the nasal capsules with the main rami of the olfactory nerve. In Cajal preparations these fibers impregnate to the exclusion of the olfactory so that they are easily followed. They are most numerous in the mid-rib between the two series of secondary folds or lamellæ. The main bundle of fibers is closely associated with an artery.

Later the ganglion has been found in a young carp, two centimeters in length. Here it appears as a compact elliptical mass of

¹Brookover, Chas., 1908. Pinkus's Nerve in *Amia* and *Lepidosteus*. *Science*, N. S., Vol. 27, No. 702, June 12, 1908, pp. 913-914.

large cells on the ventro-median side of the olfactory nerve just before it leaves the cranial cavity. This differs decidedly from the condition in the adult, where the cells are scattered, intermingling with the fibers of the olfactory nerve. Toluidin blue and thionin preparations bring out the cells with especial distinctness.

In the young of a species of *Ameiurus* about twenty-five millimeters long the ganglion has likewise been found.

In Weigert, vom Rath and Cajal preparations of the adult carp brain an unmyelinated tract can be traced caudad from a region closely associated with that in which these cells and fibers are found. At a point midway between the caudal and cephalic ends of the olfactory bulb it can easily be distinguished as it lies in the midst of a mass of myelinated fibers near the ventro-median margin of the bulb. Farther rostrad, however, these myelinated fibers end and the tract is lost among the unmyelinated fibers of the olfactory nerve in the region where the ganglionic cells first appear. Throughout the long olfactory crus the tract is plainly evident on the ventro-median side partly enclosed by myelinated tracts. On reaching the hemispheres it turns dorso-laterad, still closely associated with one of the myelinated secondary olfactory bundles, the tractus olfactorialis medialis. At the level of the anterior commissure the tracts from the two sides turn abruptly mesad and largely decussate in the mid-line, apparently ending in a dense mass of small cells at the meson. Probably part of the fibers do not cross the mid-line but end on the same side.

It should be borne in mind that the connection between this tract and the peripheral ganglionic cells and fibers has not been established and can not be except by fortunate Golgi or Cajal preparations. There is very little doubt, however, that this is the nervus terminalis, or nerve of Pinkus, for the following reasons. The peripheral ganglion and fibers are practically identical with those found by Brookover¹ in *Amia* in connection with this nerve. The condition is likewise very similar to that found by Pinkus, '94,² '95,³ in

¹Loc. cit.

²Pinkus, Felix, 1894. Ueber einen noch nicht beschriebenen Hirnnerven des *Protopterus annectens*. *Anat. Anz.*, Bd. 9, Nr. 18, 1894, pp. 562-566.

³Pinkus, F., 1895. Die Hirnnerven des *Protopterus annectens*. *Morph. Arb.*, Bd. 4, Hft. 2, pp. 275-346, Taf. XIII-XIX.

Protopterus, by Sewertzoff, '02,⁴ in *Ceratodus* and by Locy, '99,⁵ '03,⁶ '05,⁷ '05,⁸ in Selachians. The central tract follows a course similar to that described by Locy for the *nervus terminalis* in Selachians where the central connections have been established in some detail. Especially strong support comes from the findings of Herrick, '09,⁹ in the frog where the central course of the tract is almost identical with that in the carp and where the nerve leaves the brain rostrad to run in the meninges so that there can be no doubt as to its character.

THE NERVUS TERMINALIS (NERVE OF PINKUS) IN THE FROG. By C. JUDSON HERRICK, *University of Chicago*.

A nerve is here described in the frog which corresponds in its intra-cerebral course very closely to the new nerve found by Pinkus in *Protopterus* and by Locy in Selachians and termed by Locy the *nervus terminalis*. Its relations are essentially similar in both larval and adult frogs (*Rana pipiens* and *R. catesbiana*). Its fibers enter the cranium mingled with those of the *nervus olfactorius*. In the tadpole they enter the rostral end of the olfactory bulb as a compact bundle among other fascicles composed of *fila olfactoria* destined to terminate in the glomeruli of the olfactory bulb. The *nervus terminalis*, however, passes caudad through the bulb, making no demonstrable connections with the bulb, to terminate in free arborizations in the lamina terminalis among the cells of the nucleus medianus septi. In the adult frog the *nervus terminalis* separates from the

⁴Sewertzoff, A. N., 1902. Zur Entwicklungsgeschichte des *Ceratodus forsteri*. *Anat. Anz.*, Bd. 21, Nr. 21, Aug., 1902, pp. 593-608.

⁵Locy, W. A., 1899. New Facts Regarding the Development of the Olfactory Nerve. 14 figs. *Anat. Anz.*, Bd. 16, Nr. 12, 1899, pp. 273-290.

⁶Locy, W. A., 1903. A New Cranial Nerve in Selachians. *Mark Anniversary Vol.*, Art. III, pp. 39-55, pls. V-VI, 1903.

⁷Locy, W. A., 1905. A footnote to the ancestral history of the vertebrate brain. 5 figs. *Science*, N. S., Vol. 22, No. 554, Aug. 11, 1905. pp. 180-183.

⁸Locy, W. A., 1905. On a newly recognized Nerve connected with the Fore-brain of Selachians. 32 figs. *Anat. Anz.*, Bd. 26, pp. 33-63, 111-123, 1905.

⁹Herrick, C. J., 1909. The *Nervus Terminalis* (nerve of Pinkus) in the Frog. Report at Assoc. Amer. Anat., Baltimore meeting, 1909.

nervus olfactorius ventrally of the olfactory bulbs and passes caudad in the meninges to a point behind all of the glomeruli of the bulb. Here it turns dorsally and medially to enter the ventro-medial wall of the hemisphere, within which it continues caudad as far as the lamina terminalis, where it rises up and clearly decussates among other fibers of the anterior commissure. Its exact terminus was not demonstrated in the adult, but is probably in the adjacent nucleus medianus septi, as in the larva. The peripheral relations of this nerve of the frog are still unknown.

THE MORPHOLOGY AND SUBDIVISION OF THE FOREBRAIN VESICLE
IN VERTEBRATES. By JOHN B. JOHNSTON, *University of Minnesota.*

The paper contained a discussion of the general morphology of the telencephalon and diencephalon from the genetic point of view and suggestions for some revisions of nomenclature. The new facts brought forward concerned the identification of the velum transversum and paraphysis in mammals and certain changes in the relations of structures in the pars optica hypothalami (His) in the ontogeny of amphibians and mammals. The neural folds in the early embryo meet in a transverse fold, the *terminal* or *limiting ridge*, bounding the neural plate in front. Behind this a transverse groove connects the two optic pits on the open neural plate. When the neural plate rolls up into a tube, the limiting ridge forms the lower boundary of the neuropore, and the groove behind it continues to connect the optic vesicles. This is the *primitive optic groove*. When the optic tract grows from the retina into the brain, the fibers cross in the limiting ridge to form the optic chiasma. In the side walls of the brain, ridges are formed, which run from the chiasma caudo-laterad obliquely across the primitive optic groove and separate the optic vesicles from the pit behind the chiasma. The optic vesicles are, then, left in connection with a pit in front of the chiasma occupying the lower part of the neuropore space. This is the pit which in later embryos and adults has been called, since His, the optic recess. It is such only secondarily. It should be called the preoptic recess, while the primitive optic groove behind the chiasma

should be called the postoptic recess. The preoptic recess must not be confused with the neuroporic recess, which occupies the upper part of the neuropore. The postoptic recess has often been confused with the infundibular recess, which, in embryos of all vertebrates, is situated farther caudad and has connected with it the neural part of the hypophysis.

The velum transversum in mammalian embryos lies immediately behind the interventricular foramina, and in later embryos comes to be involved in the plexus chorioideus and lost from view. In all vertebrates it marks the boundary between diencephalon and telencephalon dorsally. Since the optic chiasma is found in the limiting ridge of the neural plate, it occupies the extreme anterior portion of the floor plate of His. If the telencephalon is a complete segment or ring of the brain, as His defined the term, there is no alternative but to include the optic chiasma in it. On the other hand, since all the structures of the telencephalon are formed from the portion of the neural tube in front of the optic vesicles, the telencephalon should not be made to include in the adult anything behind the primitive optic groove. In mammals, when both velum transversum and postoptic recess disappear, the boundary between diencephalon and telencephalon may be described as passing immediately behind the interventricular foramen and the optic chiasma.

The paraphysis is present in pig embryos just in front of the velum transversum as in lower vertebrates.

THE LIMIT BETWEEN ECTODERM AND ENTODERM IN THE MOUTH
AND THE ORIGIN OF THE TASTE BUDS. By JOHN B. JOHNSTON,
University of Minnesota.

In *Amblystoma punctatum* no mouth-pit or stomodeum is found. Instead, when the hypophysial invagination begins, the ectoderm of the mouth plate commences to degenerate and eventually disappears. About the borders of the mouth plate the ectoderm turns in, forming a sort of collar around the entoderm which projects to the free surface. The tucked-in ectoderm constitutes dental ridges which eventually give rise to the maxillary, vomerine and mandi-

bular teeth. For a long period the cavity of the foregut is obliterated by the coalescence of its walls and by the time the mouth opening appears the teeth are well formed, and the taste buds are forming. The formation of the mouth opening takes place by a cleaving of the entoderm, which reaches to the free surface as above described, and the mouth is lined by entoderm to the very lips. The teeth, then, pierce the entoderm to enter the mouth cavity. Some time before the mouth opening is formed, taste buds make their appearance on the roof and floor of the oro-pharyngeal cavity and on the inner surface of the gill arches. At the moment that the mouth cleft is forming, entodermal cells begin to arrange themselves into taste buds in the region of the vomerine teeth, on the tongue and close behind the maxillary teeth. All the taste buds of *Amblystoma* are of entodermal origin. This is an exception to the supposed law that all nervous structures are derived from ectoderm, and the writer believes that other structures, such as the palatal and intestinal plexuses, require to be investigated with regard to their possible origin from entoderm.

Other facts brought out were: the continuity of hypophysial and neuroporic thickenings in early stages; indications of a connection of hypophysis with archenteron; the presence of preoral entoderm and premandibular somite as in selachians; the union of the nasal sacs with the mouth cavity takes place by way of the preoral entoderm.

THE NERVES OF THE ATRIO-VENTRICULAR BUNDLE. By J. GORDON WILSON, M.A., M.B. *Hull Laboratory of Anatomy, University of Chicago.*

As a result of the examination of the bundle in the calf, sheep and pig, the following conclusions were arrived at:

I. Anatomically the atrio-ventricular bundle contains not only a special form of muscle fiber distinct from the ordinary muscle of the atrium or the ventricle but is an important and intricate nerve pathway in which we find:

1. Numerous ganglion cells—monopolar, bipolar, and multipolar—whose processes may pass

a. to adjacent ganglion cells in the bundle

- b. to the muscle fibers in the bundle,
- c. through the muscle bundle so far as it was examined.
- 2. Abundant nerve fibers running through it in strands, the processes of which may end
 - a. in ganglion cells in the bundle,
 - b. in the muscle plexus,or may pass through the part examined.
- 3. An intricate plexus of varicose fibrils around and in close relation to the muscle fibers of the bundle.
- 4. An abundant vascular supply with well marked vasomotor nerves and sensory endings.

II. Physiologically it has been shown that the atrio-ventricular band constitutes the pathway which assures the communication of the atrio-ventricular rhythm. When the bundle is sectioned or crushed, the ventricles cease momentarily to beat though they soon regain pulsation but with a rhythm much more slow than that of the atrium. Pathological anatomy supports this view; the allorhythmia of Stokes-Adams disease can be explained satisfactorily by lesions involving this pathway. As a result of these physiological experiments and from these pathological conditions, it has been asserted that the contraction wave must be myogenic. To such a deduction my anatomical findings are opposed. They demonstrate that in these experiments and pathological conditions an important nerve pathway is equally involved with the muscle bundle. Considering the neurogenetic as opposed to the myogenic hypothesis from the anatomical standpoint, one must acknowledge that the very complex nerve constituents of the bundle indicate an important nerve pathway and are very suggestive of an intricate nerve mechanism.

IS THE ATRIO-VENTRICULAR BUNDLE TO BE REGARDED AS A NEURO-MUSCULAR SPINDLE? By J. GORDON WILSON, M.A., M.B.
Hull Laboratory of Anatomy, University of Chicago.

The essential anatomical points in the structure of the neuro-muscular spindle, namely, its shape, its lymph spaces, its lamellar capsule, its arrangement of muscle fibers, have nothing similar in the atrio-ventricular bundle. To these must be added that the nerve

endings of Ruffini so distinctive of the spindle have nothing comparable in the bundle, and that ganglion cells are present in the bundle and absent from the spindle. From this it must be concluded that whatever the physiological significance of the bundle may be, it has anatomically nothing in common with the neuromuscular spindle.

THE INTERSTITIAL CELLS OF THE TESTIS OF AN HERMAPHRODITE HORSE. By RICHARD H. WHITEHEAD, *Anatomical Department, University of Virginia.*

For the material and photographs of this case I am indebted to the kindness of Professor S. H. Gage, of Cornell University. The horse was a pseudo-hermaphrodite colt two or three years old. The general type of the animal was distinctly masculine, while the external genitals were those of a mare. Operation revealed normal female genital passages including a normal uterus, but the essential organs proved to be testes. After the operation of removing the testes, the horse became a useful animal. Histological examination showed that the epithelium of the seminiferous tubules consisted entirely of Sertoli cells, whereas the interstitial cells were typically formed and exceedingly numerous. The structure of the organ was thus quite similar to the ordinary abdominal testis of cryptorchids. Granules such as I have described in the interstitial cells of various mammalian testes were not present, but this can be explained by the fixative used—a solution of picric acid in alcohol. The essential features of the case are the coexistence of male characters with female genital passages, and the presence of undescended testes. It furnishes additional evidence in favor of the view that the male characters of mammals are correlated with the interstitial cells of the testis.

**OCCURRENCE OF SUPERNUMERARY NIPPLES IN THE MALE, BASED
ON AN EXAMINATION OF COLLEGE STUDENTS. By JOSEPH H.
HATHAWAY, *Cornell University Medical College, Ithaca.***

In the course of physical examinations made on 2561 students at

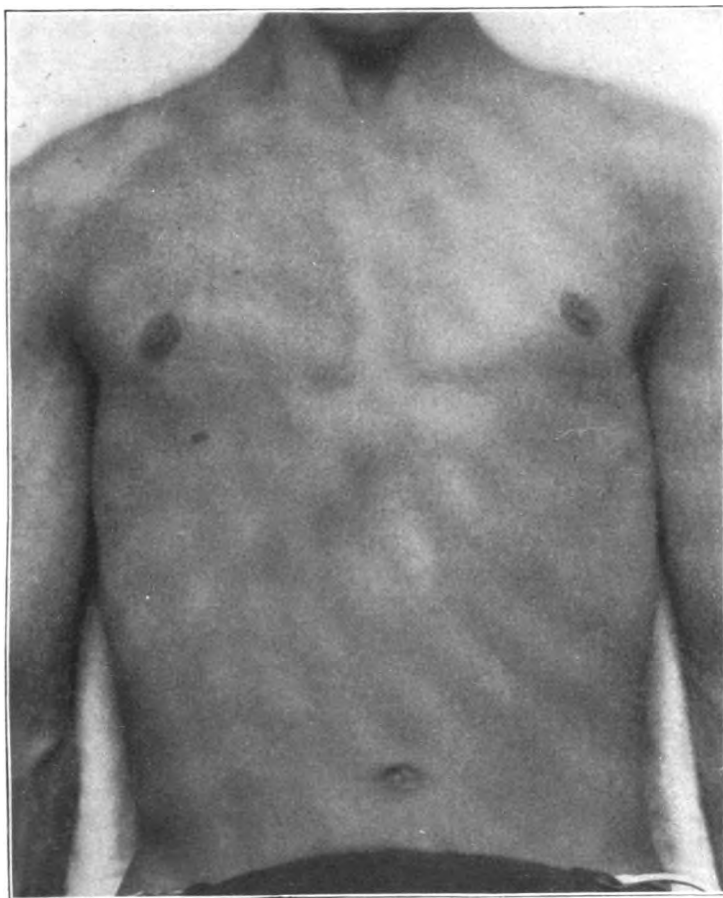


FIG. 1.—Case No. X 3172. An example illustrative of the cases of supernumerary nipples as found in the male—in this case occurring on the right side and below the normal nipple.

the Cornell University Gymnasium there were observed 21 cases or 0.82 per cent in which supernumerary nipples occurred. Only three cases were observed in the examination of the first 1082 students and

the number of occurrences was probably greater than this as the nipples were not looked for especially at this time. Ten cases, or 0.87 per cent were observed in the examination of the next 1152 students; and

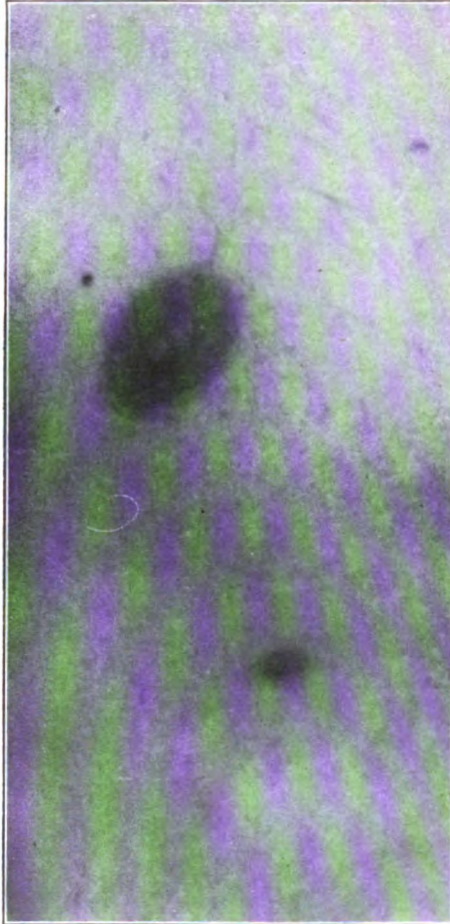


FIG. 2.—Case No. X 3172. An enlargement from the negative in Fig. 1 showing the supernumerary nipple more in detail.

in the remaining 327 students, 8, or 2.45 per cent, were found having supernumerary nipples. These last 327 men were all farmers attending the Agricultural College and it is interesting to note the

fact of such a high percentage in this class of men as compared with men coming from various conditions of life in general.

In two cases the nipples were paired and located between the normal nipples and the umbilicus. In one of these men there were distinct and well developed papillary elevations surrounded by the pigmented areola. The extra pair of nipples in the other man consisted of small lightly pigmented spots about 4 mm. in diameter, in the nipple line and just above the umbilicus. This case is of particular interest as three other cases were recorded, where there was a pigmented spot on one side only and in the nipple line but which the man was positive had always been present, and these were undoubtedly traces of extra nipples, although from their small size and lack of papillary elevation they might readily be overlooked or mistaken for a slight pigmented skin lesion.

Besides the two cases in which the nipples were paired, there were seven of the cases in which they occurred on the right side below the right nipple and eight cases occurring below the left nipple. In two more cases the extra nipple occurred above the normal right nipple just outside the margin of its areola. These two cases had distinct papillary elevations; in one of these cases there was also a trace of an extra nipple in the left iliac region.

The one case remaining had a large deeply pigmented areola about 15 mm. in diameter with a large distinct papilla. This nipple was situated below and to the left of the umbilicus.

KEIBEL'S NOTE ON INTESTINAL DIVERTICULA. By FREDERIC T. LEWIS,
Harvard Medical School, Boston.

In the paper on intestinal diverticula which Professor Terry kindly presented for me at the last meeting of this Association, and in the subsequent publication by Dr. Thyng and myself, no mention was made of a previous note upon the same subject by Professor Keibel. This note, which forms a concluding paragraph in a paper entitled "Zur Embryologie des Menschen, der Affen und der Halbaffen" (*Verh. d. anat. Gesellschaft*, 1905, p. 39-50), is of such interest and so brief that it may be quoted in full, as follows:

"I come now to a peculiar observation, which I first made on the small intestine of ape embryos, between the orifice of the ductus choledochus and caecum. I found here, in the epithelium of the mucosa, peculiar buds similar to taste-buds or perhaps to hairs in their earliest stages. Later these developed into little diverticula. Then I found similar structures in man, *Tarsius*, the pig and the deer. The further development of the buds or diverticula I have not yet been able to follow. The accompanying figures show a number of such epithelial buds from human and *Tarsius* embryos. It is strange that these buds and diverticula were not mentioned by Voigt (1899) and Berry (1902). It is important that the development proceeds throughout from the epithelium and that the mesoderm is only secondarily involved. Moreover, the further development of the buds differs in different animals."

The early stages of the diverticula, which Professor Keibel describes as *buds*, we have called epithelial *pearls*; it is clear that his note and our paper deal with the same structures.

In regard to the possibility that diverticula in the adult arise from these pockets in the embryo, a publication by E. Hedinger is of interest (*Arch. f. path. Anat.*, 1904, Vol. 178, p. 25-43). After describing several diverticula in the vermiform process of a child at birth, he states: "Our case represents not only the first observation of congenital diverticula of the processus vermiformis, but also, so far as the literature shows, the first certain proof of such a congenital formation in the entire extent of the intestinal tract." However, Hedinger cites several cases of diverticula found after birth which were believed to be congenital, among them a case of diverticulum of the oesophagus described by Glockner. In a human embryo of 22.8 mm. I have seen several diverticula of the oesophagus, and the possibility of their pathological persistence and enlargement must be considered. The structures found by Hedinger in the vermiform process have at least a superficial resemblance to the diverticula of the embryo.

I have been informed that the embryonic diverticula have, for some time, been studied in Professor Keibel's laboratory, and a further publication concerning them may be expected.

FURTHER OBSERVATIONS ON SUBCUTANEOUS AND SUBPANICULAR HÆMOLYMPH NODES. By ARTHUR W. MEYER, *Professor of Anatomy in the Northwestern University Medical School.*

Since the only observations which I was able to find in the English language on this subject, is a short summary published in the Proceedings of the Association last year, it seems justifiable to quote from that note:

"On the examination of carcasses of beeves in abattoirs a number of hæmolymp nodes can usually be found lying in the subcutaneous fat over the neck and shoulder and, more particularly, in the region directly anterior to the hip. These nodes vary in number from one to a dozen on each half of the carcass and have the same appearance as those in the lumbar pre-vertebral region. They vary in size from a half to one and a half centimeters, are oval or circular in outline and usually flattened laterally. In color they vary from a bluish-black to a bright red or pale pink. They are usually firm, the blood cannot be expressed from them by pressure, and injections of India ink fail to reveal any lymphatic vessels. They are most numerous in young cattle and were found in fœtuses of twenty-two or more centimeters in length. In old cattle they are generally small or absent altogether.

"Their structure is very similar to that of the hæmolymp nodes of sheep, and as wide variations in structure were found to exist. Such differences as exist are minor even in case of developing nodes. In the latter the occurrence of giant cells is particularly noticeable, and, as in the case of developing hæmolymp nodes of the sheep, they arise from mesenchyme."

In order to test further the existence of lymphatic vessels in the mature nodes, a number of carcasses which contained large and easily-accessible nodes were selected from a lot of eighty, condemned because of tuberculosis, pyemia, bruises, etc. Various suspensions and solutions including Prussian and methylene blue and India ink were injected into the nodes by means of puncture with a syringe holding twenty-five cubic centimeters. Since the nodes are so large there is no difficulty in avoiding transfixation of the node or extravasation of the fluid. By detaching the barrel of the syringe when

re-filling was necessary repeated puncture of the node was avoided and the injection of large quantities of fluid into the same node made possible. In this manner it was determined that all nodes lying over the lateral thoracic region communicated with the intercostal veins and thence with the main thoracic trunks. In a number of cases enough fluid was injected so that it trickled out of the azygos veins at their cut thoracic ends and ran to the floor. Although a pressure of several pounds could occasionally be used after clamping of the efferent vein, it was never possible to inject lymphatic vessels. Furthermore to avoid error pieces of the injected vessels draining the nodes were excised and examined microscopically.

A striking peculiarity of many of these nodes is their firmness. There is great resistance to the needle, and penetration is generally accompanied by a crunching sound as if cartilage were pierced. This peculiarity, I take it, is due to the extraordinary large trabeculæ. Indeed, the most characteristic thing about the microscopic appearance of these nodes is the thickness of the capsule and the extraordinary size of the trabeculæ. It is very rare to find hæmolymp nodes in the sheep or goat with trabeculæ of corresponding size.

Lymphatic spaces or vessels were never seen within the nodes; and the widest variations in the quantity of blood and lymphatic tissue exist. In some nodes only small isolated masses of lymphoid tissues were left containing many large full blood spaces which communicated directly with the much larger surrounding mass of red cells. These large areas of red cells, among which almost no white cells were found, were frequently bounded by thick strands of connective tissue in which very numerous, irregular, anastomosing, empty blood-spaces and vessels were found. This was also the case in the thick layers of connective tissue found beneath the capsule of some nodes. The picture in these nodes, in short, was one of depletion of lymphatic tissue and marked sclerosis.

In order to determine at what age these nodes first make their appearance in bovine fœtuses a series of dissections were made in the abattoir immediately after evisceration. In all young fœtuses it is very easy to strip off the skin after cutaneous incisions. Since the

small embryonic nodes resemble punctate hemorrhages or minute blood clots very closely, a jet of warm water or gentle stroking with the bare hand was made use of to keep the field of observation free from blood. By this means it was not very difficult to distinguish between hæmolymph nodes and small clots or the ends of bleeding vessels even when they were mere specks.

Out of several dozen fetuses examined in this manner nodes were detected in those, 22, 28, 30, 32.5, 38 and 40 cm. long and almost always in those at term, although because of economic reasons, only a few of the latter were examined. The number of nodes found varied from one to six and the size from mere specks to one and a half to two millimeters. Most of them were found in the pre-crural region and all looked like blood clots to the unaided eye. On section they varied much in appearance however. The earliest contained but little blood and this was almost wholly in vessels, while the older specimens contained but little lymphoid tissue but much blood, mostly all of which was scattered among the lymphoid tissue. The trabeculæ were larger in older nodes, there was a better-defined capsule of varying thickness and a peripheral sinus containing blood. All the nodes contained a reticulum composed of branching cells, the processes of which were often of considerable length and great tenuity. The reticulum bounding the peripheral sinus or the central spaces often seemed to form a definite endothelial-like layer.

Besides erythrocytes and lymphocytes a cell the size of the polymorphonuclear leucocyte, the cytoplasm of which took an acid stain, was commonly seen. These cells had a round, vesicular nucleus or several irregularly-shaped nuclei, but seldom contained sufficiently definite granules to justify one in classing them as eosinophiles. Much larger cells with like staining reactions containing a single composite nucleus apparently composed of from six to twelve nuclei or several separate nuclei were found in almost all sections. Pigmented cells or lymphatic vessels were not found in the developing node.

THE OCCURRENCE OF INTRA-THORACIC PARATHYROID GLANDS. By
ARTHUR W. MEYER, *Professor of Anatomy in the Northwestern University,
Medical School.*

It will be recalled that the thymus in the sheep extends from the angle of the jaw to the heart. That a large pyramidal portion lies in the angle formed by the parotid and submaxillary salivary glands and the dorso-cervical muscles, directly caudad from the ventral border of the pinna, and medial to the jugular and maxillary veins. This portion is united by a very slender cord which lies directly ventral to the carotid artery and medial to the jugular vein, with the voluminous inferior cervical portion. The latter fills all the space between the thyroid gland and the thorax. It is bifid at its upper pole, tapers gradually to a point at its lower pole, to adjust itself between the jugular veins at their junction. Directly ventral to this junction, a very short thin cylindrical portion pierces the thorax, thus uniting the extra and intra-thoracic portions. The latter lies to the left of the supra-pericardial lobe of the lung and is about one-half its size. The weight of the thymus at birth is about 7-10 grams, and it often reaches a weight of 85 grams in lambs four months old.

In a report made two years ago it was stated that the parathymus glands of the sheep "may be anywhere in the region occupied by the thymus itself." At that time no intra-thoracic parathymus gland had been found, but, from embryological facts, it was clear that the finding of such a specimen or specimens was merely a matter of careful search. In order to determine the correctness of this opinion, a series of 63 sheep foetuses from 4.9 to 39 cm. were carefully dissected.

In sixty per cent of these cases the parathymus gland was found on the lateral or median surface of the dorso-cephalic portion of the superior part of the cervical thymus. In twenty per cent of the cases it was found on that portion of the thymus which lies between the stylo-maxillary muscles laterally, and the pharynx medially. In this position, it always lay high up, near the base of the skull and frequently remained behind when that portion of the thymus was withdrawn. In eleven per cent of the cases, it lay in a position in-

intermediate between these; in six per cent, somewhere in the remaining part of the thymus—extra or intra-thoracic; and in three per cent of the cases, the gland was not found.

It follows, then, that the parathymus gland in the sheep is in relation with the cephalic surface of the superior cervical portion of the thymus in ninety-one per cent of the cases. Aberrant glands have been found in all parts of the thymus below this region, and it is unlikely that the finding of an intra-thoracic para-thymus will long remain unique.

Accessory parathymus glands were found in three per cent of the cases. One of these was microscopical in size, one barely visible, and the rest about the same size as those in the usual position. The occurrence of accessory parathymus glands is not at all unusual. In a series of several hundred fetuses from 7.8 to 38 cm. dissected in 1906, four were incidentally found to possess accessory parathymus glands. Had a more careful search been made with this object in view, the proportion would undoubtedly have been greater. The largest number of such glands found in a single fetus was two. Since, however, nothing but a lens was used to assist in distinguishing these glands, and since, moreover, the slices of the thymus gland were about three millimeters thick, it is evident that some must have escaped notice. This manner of examination probably also accounts for occasional failures to find a parathymus gland in a given fetus.

The relation of the parathymus to the thymus gland is a very variable one. Usually, it is imbedded partly or wholly in the substance of the thymus and rarely it is found so deeply buried that it can only be found by microscopical examination. In many young fetuses it is connected with the substance of the thymus by one or two stalks composed partly of parathymus and partly of thymic tissue. In the older fetuses, this connection becomes less intimate as a rule, in spite of the increasing size of the thymus.

Among the sixty-three fetuses, one 25 cm. long was found in which an accessory parathymus gland about one millimeter in size was imbedded in the center of the free surface of the intra-thoracic lobe of the thymus. Although a microscopical examination was

made later, the color and size of this gland were so typical that there was no doubt about its identity from gross appearances alone. This specimen had a definite, though loose, connective tissue capsule, delimiting it from the thymus, and was typically parathyroid in structure, except that it contained well-defined alveoli apparently containing colloid.

The occurrence of vesicles containing colloid is not common in embryonic parathymus glands. Rarely, however, one or more of these vesicles may have become cystic in structure and sufficiently large to be visible to the naked eye. Such a cyst was found in a parathymus gland taken from a foetus 26 cm. long. This cyst, which was multi-locular, included one-fifth the area of the parathymus and was bounded by a layer of flattened epithelium for a part of its extent.

THE GLANDS OF THE FRONTAL SINUS OF THE SHEEP. By **ELBERT CLARK**, *Assistant in Anatomy, University of Chicago.*

The frontal sinuses of the sheep are relatively large and nearly always contain a great amount of mucus. The mucus is derived from the goblet cells of the epithelial layer of the lining membrane and from mucous glands. Glands were found in all the sinuses examined. They are of two types— intra-epithelial glands and glands in the tunica propia. The intra-epithelial glands are small cup-like depressions in the epithelial layer. They are always numerous and are quite generally distributed over the entire lining membrane on both posterior and anterior walls. The glands in the tunica propia are of two kinds—the smaller tubular glands, usually somewhat coiled, and the larger alveolar glands with most often only a single alveolus.

The tubular glands are found in that part of the membrane lining the inferior lateral portion of the sinus—the region of the ostium. The alveolar glands occur for the most part in the lining membrane of the anterior wall. They are most numerous in the upper and upper lateral parts.

Glandular elements also occur in crypts and furrows of the lining membrane. Small lymph nodules are found here and there. It

is not uncommon to find in the tunica propia small and large mucous cysts lined with cubical epithelium.

It is possible that there is represented in these granular structures different stages in the development of the larger mucous glands. A crypt may be considered as an intra-epithelial gland, which extends down below the surface epithelium into the tunica propia. An alveolar gland of the tunica propia may be thought of as a dilated crypt whose walls have become mucus-secreting.

ON THE VARIATIONS OF THE PALMARIS LONGUS MUSCLE. (AN ABSTRACT.) By J. PARSONS SCHAEFFER, M.D, *Instructor in Anatomy, Cornell University Medical College.*

The palmaris longus muscle varies in form, origin and insertion. It may also present the interesting condition in which the muscle has undergone cleavage. It is frequently absent on one or both sides.

The muscle may be entirely replaced by a fibrous strand, or be fleshy throughout. It may have its tendon placed proximally and the fleshy part distally, or be fleshy at both extremities with an intervening tendon. It may also have its fleshy part located centrally with proximal and distal tendons.

It at times has partial or complete insertion into the fascia of the forearm. It is also reported to be occasionally attached either to the pisiform bone or to the scaphoid bone.

I have found a duplicity of the muscle, on the left side, in a cadaver, and at another time, on the right side, in a living individual. A triplicity of the muscles has also been reported by different observers.

In looking over the literature on the palmaris longus muscle, I find that much work has been done, on the determination of the presence and absence of this muscle, on the cadaver. I have, however, been unable to find any reference to work done along similar lines on the living individual. To see how closely data, so derived, would agree with data derived from a study of the cadaver, I undertook the examination of 800 living arms.

Out of 2462 cadavers reported in the literature on the palmaris

longus muscle, I find that 440 of them had the muscle absent on one or both sides, or a percentage of 17.8.

LeDouble examined 260 cadavers composed of an equal number of males and females, with results as follows:

Cadavers examined.	Muscle absent.	Right.	Left.	Both.	Per cent.
130 (male)	6 cadavers	*			4.6
.....	8 cadavers		*		6.1
.....	10 cadavers			*	7.6
Total	24 cadavers				18.4
130 (female)	9 cadavers	*			6.9
.....	14 cadavers		*		10.7
.....	17 cadavers			*	13.0
Total	40 cadavers				30.7
260 (male and female)	64 cadavers				24.6

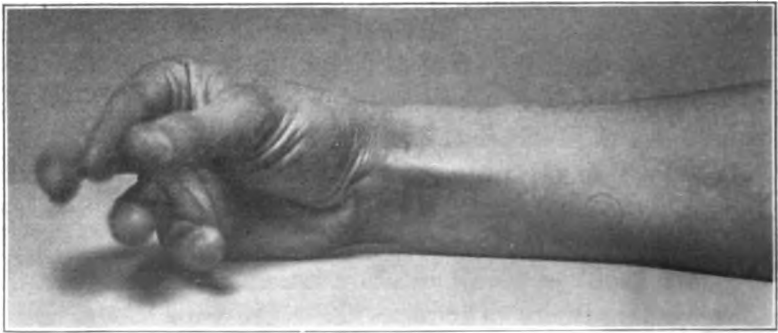


FIG. 1.

Arms examined.	Muscle absent.	Per cent.
260 (male)	34 muscles	13.0
260 (female)	57 muscles	21.9
520 (male and female)	91 muscles	17.5

I now wish to tabulate the results based on a study of 800 arms in the living individual. In each case the writer was reasonably

sure that the conclusions drawn were accurate; however, this method of determining the presence or absence of the palmaris longus muscle is not entirely trustworthy, because in cases where the muscle was very feebly developed, or markedly altered in its insertion, it may have inadvertently been classed as absent.

Number persons examined.	Times muscle was absent on one or both sides.	Per cent. of individuals.
400 (males and females).....	120	30.0
375 (males)	112	29.8
25 (females)	8	32.0

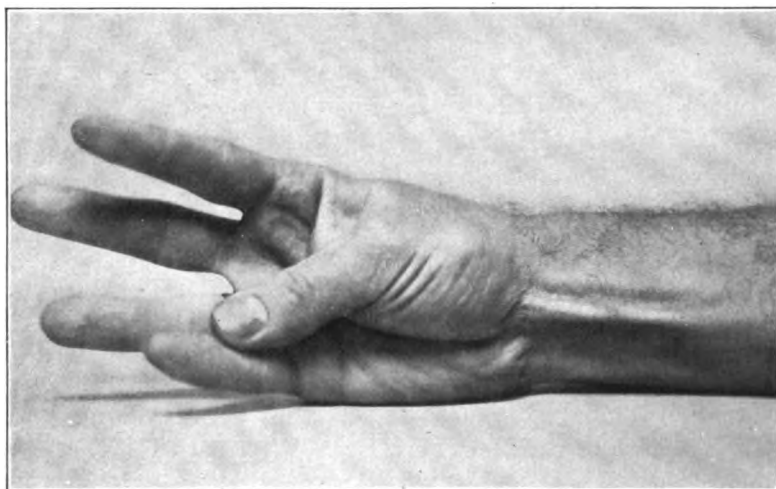


FIG. 2.

Number examined.	Times muscle absent.	Per cent. of individuals.
375 (males)	20 right side	5.3
	36 left side	9.6
	56 both sides	14.9
25 (females)	1 right side	4.0
	3 left side	12.0
	4 both sides	16.0
400 (males and females).....	20 right side	5.0
	40 left side	10.0
	60 both sides	15.0

Number of arms examined.	Times absent.	Per cent of individuals.
800 (male and female)	82 right side	10.2
	102 left side	12.7
750 (male)	77 right side	10.2
	95 left side	12.6
50 (female)	5 right side	10.0
	7 left side	14.0
<hr/>		
Total number of arms examined.	Total number of absences.	Per cent. of muscles absent.
800 (male and female)	184 (on both sides)	23.0

By a comparison of the preceding tables, it will be seen that data derived from a study of the living individual agree fairly closely with those obtained from a study on the cadaver. The arrangement of results will be noticed to be similar in both cases, *i. e.*, the greater number of absences occurring in the female, and on the left side in both sexes. The number of times the muscle is absent on both sides exceeds the number of times the muscle is absent on either the right or left side.

REPORT OF A CASE OF HERMAPHRODITISM (HERMAPHRODITISMUS VERUS LATERALIS) IN SUS SCROFA. By B. F. KINGSBURY.

The following report is made on material sent over to me by Dr. W. L. Williams, of the New York State Veterinary College, and at his suggestion:

The specimen, from a nine months pig, was received from an Inspector of the Bureau of Animal Industry at Milwaukee. The external genitals were those of a male. The penis was normal. The perineum, however, presented a well developed ridge suggesting the vulva of the female animal. The internal genital organs indicated strongly that it was a case of true hermaphroditism.

As shown in the photograph of the specimen (Fig. 1), there is the usual small corpus uteri with two relatively long and convoluted uterine horns. Dissection revealed a typical cervix and a vagina. Cornua, corpus, cervix and vagina possessed a lumen. As implied above, there was no orificium vaginae. The left cornu is

prolonged into a Fallopian tube, which terminates in a small fimbria which is attached to a body about the size of a small bean shown by microscopical examination to be an ovary. No trace was found of a testis, epididymis or vas deferens on the left side. Upon the

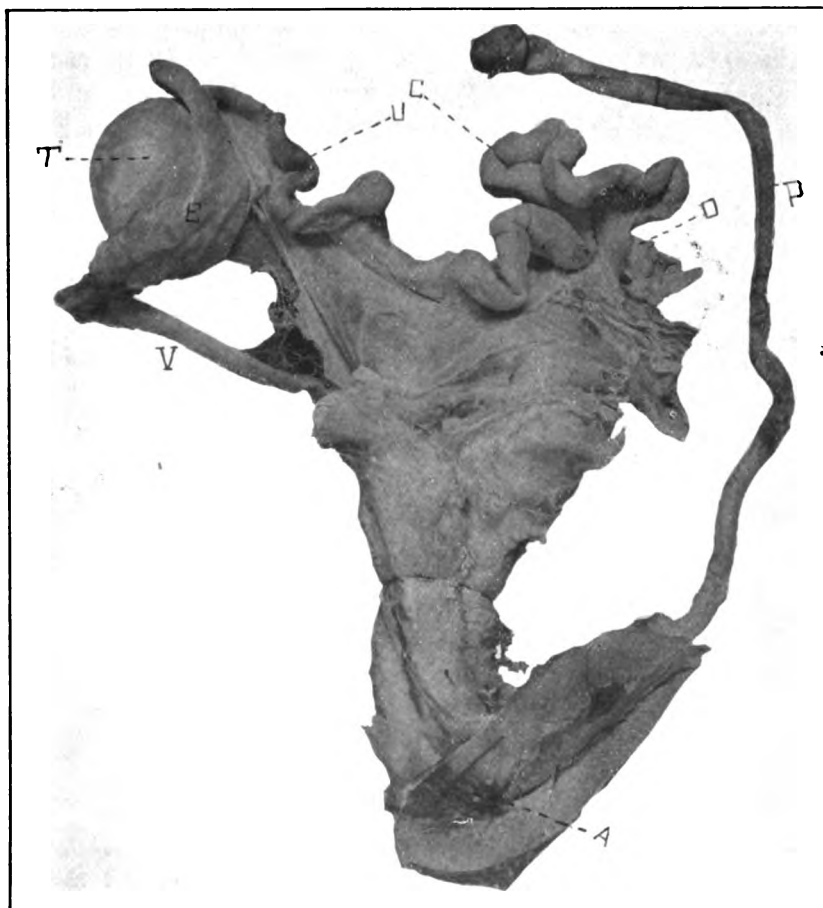


FIG. 1.

right side, however, there is an evident testis about two and one-half centimeters in length with an apparently typical epididymis and a vas deferens. The right uterine horn resembles that on the left

side. Its Fallopian tube ends, however, in a diminutive blind sac, which closely applied to the caput epididymidis with which on superficial examination it appeared to be continuous; this, however, was not found to be the case. No ovary was found on this side.

The microscopical examination of the suspected ovary on the left side was confirmatory of the diagnosis. The middle third or more of the organ was cut out and serial sections made. In the portion so examined, five follicles containing ova were found, one of them being well developed, with a cavity, cumulus, theca and stratum



FIG. 2.

granulosum. A photograph is submitted showing a young follicle (Fig. 2). Numerous small nests of cells resembling follicle cells were also found, but definite recognizable ova were absent. The stroma ovarii was of normal structure. There was no indication of testicular tissue in the sections.

A longitudinal segment of the testis was also cut out and sectioned, revealing the typical structure of a cryptorchid testis. The tubules were composed of a single layer of cells whose inner ends

were vacuolated. The interstitial cells were numerous and typical, as shown in the photograph (Fig. 3).

Adopting the classification of Klebs, the anomaly would be a case of Hermaphroditismus verus lateralis and as such seemed to me worthy of being put on record. As far as I have been able to ascertain, there are five other cases of true hermaphroditism in the

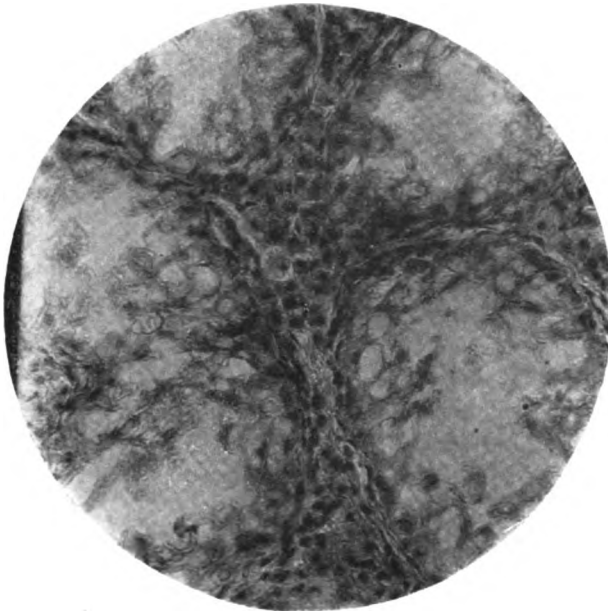


FIG. 3.

pig in which the presence of ovary and testis were determined by microscopic examination; three cases in which ovary and testis were present on both sides, described by Garth¹ and by Kopsch and Szymonowski;² one case recorded by Pütz³ of ovary and testis

¹Garth, W., '94. Zwei Fälle von Hermaphroditismus verus beim Schwein. 59 pp. Giesen, C. v. V. Münchow, 1894.

²Kopsch u. Szymonowski, '96. Ein Fall von Hermaphroditismus verus bilateralis beim Schweine nebst Bemerkungen über die Erstehung der Geschlechtsdrüsen aus dem Keimepithel. Anatomischer Anzeiger, Bd. XII, p. 129, 1896.

³Pütz, '89. Ein Fall von Hermaphroditismus verus unilateralis beim Schweine. Deutsch. Zeitschr. f. Tiermed., Bd. XV, 1889.

on one side only; a fifth case, described by Duchanek⁴ in 1894, was inaccessible to me. More instances of hermaphroditismus verus are reported in the pig than in any other mammal save man in which form six cases are on record, the diagnosis being based on microscopic examination and apparently authentic. Three of these are *H. unilateralis* (ovary and testis both present on one side only); one is *H. bilateralis* (Heppner's) (ovary and testis on both sides); while three are *H. lateralis* (ovary on one side, testis on the other).

It hardly need be said that no case in mammals is known of the presence of both ovarian and testicular tissue capable of functional activity other than possibly elaboration of internal secretions.

ON THE MODE OF DISAPPEARANCE OF THE VILLI FROM THE COLON
OF MAMMALS. By RALPH V. CHAMBERLIN, *Provo, Utah.*

By most earlier writers the disappearance of the embryonal villi from the large intestine of mammals has been associated with the formation of the crypts of Lieberkuhn, the one process being looked upon as closely dependent upon the other. Brand ('77) believed the crypts to be formed by the gradual upgrowth of ridges connecting the bases of the villi and thus leaving between them pits, the initial crypts, which, as the ridges rise, become deeper and deeper. In the large intestine he supposed the ridges ultimately to reach the tops of the villi, thus completely obliterating the latter, whereas in the small intestine the ridges grew but part way up the villi and the latter hence persisted. Patzelt ('82) and Kölliker in his later views ('84) express agreement with Brand. In an earlier view ('61) Kölliker had regarded the crypts as independent tubular downgrowths of the epithelium.

Schulze ('97), while agreeing in the main with this explanation, thought that from the bottoms of the pits left between the upgrowing ridges there were additional hollow downgrowths, the crypts being formed, he supposed, thus partly through upgrowth of the ridges and partly through independent downgrowth. Kollmann ('98),

⁴Duchanek, J. O., '94. Hermaphroditismus beim Schweine. Tierärztl. Centralblatt, Bd. XVII, p. 1, 1894.

going still farther, concluded that the crypts were formed exclusively as downgrowths between the villi and wholly independently of the latter. His results as to this point were confirmed by Voigt ('99) and by Hilton ('02).

Seeking to determine the manner of disappearance of villi from the colon in accord with his findings as to the formation of the crypts, Voigt, without any stated evidence, advanced the view that because of rapid growth there was, it is to be inferred, a stretching out of the epithelium such as to result in the complete retraction of the villi. The same view has since then been stated by others.

From a detailed study made in Prof. Gage's laboratory in 1902 upon the alimentary canals in a complete series of pig embryos, I was able to reach the following conclusions:

The earlier stages of development in large and small intestine are essentially the same, the latter, however, preceding the greater portion of the former considerably. The villi are formed mainly in the way first correctly described by Berry ('00), who worked on *Homo*, through the progressive breaking up of distinct longitudinal ridges. In the mid-colon, where the villi are latest to form, their maximum relative length is attained in embryos about 17 cm. long. They are then from cylindrical to clavate in form. In embryos successively older than this it was found that the villi soon lose the clavate or cylindrical form and become apically drawn out to a point, there being clearly reduction or shifting downward of the connective tissue core. This process results soon in the collapse of the epithelium covering the apical portion of each villus. The cells of the portion of epithelium thus no longer in contact with the connective tissue are sloughed off singly or in groups, the remaining epithelial sheath constantly adjusting itself anew over the reduced villus. This process continues until the general level of the mouths of the crypts of Lieberkuhn is reached, the villi as such thus becoming wholly obliterated.

It was found from a study of ample material placed at my disposal through the courtesy of Dr. Hilton that the villi in the colon of the white rat disappear in essentially the same way as in the pig.

Schirman's statement ('98) that the villi in the colon of the

guinea-pig consist for the upper portion of their length entirely of epithelium is doubtless to be interpreted in accordance with these results as applying to the stage immediately before disappearance.

In order to compare in some degree the relative rates of growth in large and small intestines, measurements of the diameters of definite portions of the lower ileum and of the mid-colon were made in such specimens as were available. A plotting of curves from the measurements obtained seemed to indicate comparative uniformity in the rate of increase in diameter of the ileum. The curve for the colon lies below that for the ileum at the outset; but, as embryos of the stage in which the villi have attained a maximum development, as before indicated, are reached, there begins an acceleration, it appears, in the rate of growth of the colon with the result that its curve soon crosses over above that of the ileum and diverges from it until the embryos are from 30 to 34 cm. in length. It is during this period of accelerated growth in the colon, that is when the embryos are from 20 to 30 cm. long, that its villi disappear.

THE DEVELOPMENT OF THE VEINS IN THE BODY WALL OF THE
PIG. By HELEN W. SMITH, *Anatomical Laboratory, Johns Hopkins University.*

This communication was presented by way of a demonstration of specimens showing the development of the veins in the body wall of the pig.

These specimens show in the earliest stages (7 mm.) the capillaries of the limb bud draining partly into the posterior cardinal and partly into the umbilical vein. Following the development of these blood vessels we find that, at different stages, the superficial body wall drains in great part (1) into the posterior cardinal (2) into the umbilical vein, (3) by way of the thoraco-epigastric into the axilla, (4) finally into the internal mammary.

These changes are effected gradually as follows: The umbilical vein shifts forward and the membrana reuniens is seen filled with blood vessels draining into the umbilical vein from the limb bud and the myotomes (as described by Coste, etc.). As the muscle layer invades the membranous lateral body wall the vessels of the

membrana gradually atrophy and disappear in consequence of the formation of a secondary system which carries the blood from the body wall to the axillary region. This is accomplished by the formation of a chain of capillaries along the body wall that anastomose beneath the arm bud with the primitive ulnar. The primitive ulnar is connected anteriorly with the general capillary mesh which surrounds the artery to the limb bud and empties into the anterior cardinal at its junction with the posterior cardinal. These capillaries enlarge to form a good-sized vessel, running from the body wall beneath the limb bud, receiving the primitive ulnar and emptying into the anterior cardinal. In earlier stages it forms a loop around the artery, but later only the central part of the loop persists. This is the thoraco-epigastric vein and is identical with the "external mammary" described in the rabbit embryo by Dr. F. T. Lewis.

This vein increases in size until it, together with the superficial epigastric, which has formed at the same time and with which it is practically continuous, drains almost all the superficial body wall. The inner body wall is drained by the internal mammary vein and deep epigastric, which lie on the mesial edge of the muscle layers and have been carried ventrally with it. They are connected with the dorsal vessels by the intercostals, and have numerous anastomoses with the thoraco-epigastric. These anastomoses enlarge at a point just below the tip of the sternum, with the result that a channel is formed which deflects the course of the blood from the whole lower part of the thoraco-epigastric into the internal mammary, leaving only the stump of the vessel draining into the axilla.

A CASE OF CYCLOPIA.¹ BY R. H. WHITEHEAD. *From the Anatomical Laboratory, University of Virginia.*

Deified by the ancients, regarded with holy horror in the middle ages, exhibited as curiosities on the shelves of museums in later times, human monsters have always been subjects of great speculative interest. It is only in comparatively recent times, however,

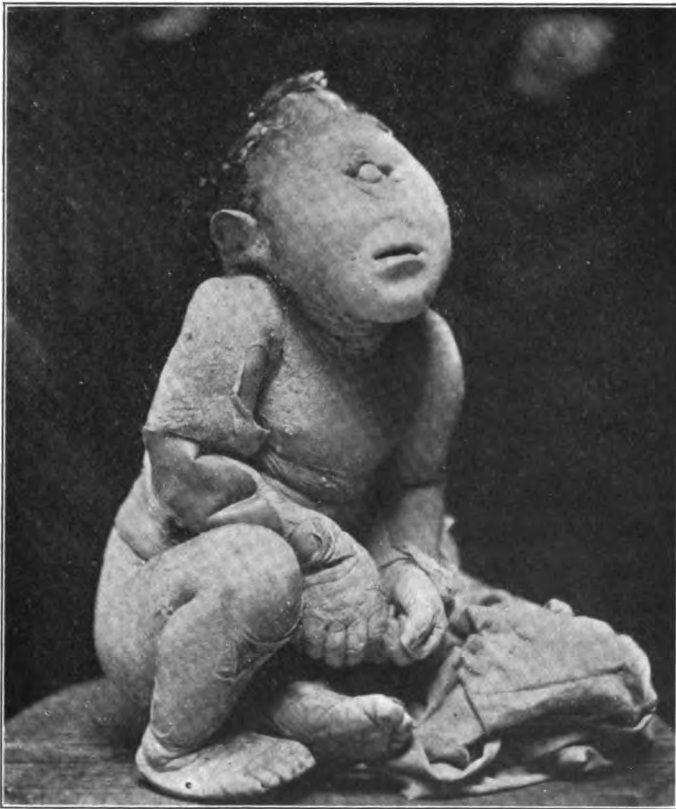
¹Preparation demonstrated at the twenty-fourth session of the Association of American Anatomists, Baltimore, Maryland, December 20-31, 1908.

that they have been treated as objects of serious scientific study. Professor Wilder's (H. H. Wilder. *The Morphology of Cosmobia*, Amer. Jour. Anat., Vol. VIII, No. 4, 1908) laudable attempt to bring some order into the chaos of our knowledge concerning the genesis of monsters has encouraged me to put on record a case of cyclopia which I have been holding back for various reasons, the principal one being the hope of obtaining more material for comparative study. Wilder believes that he can establish a fairly complete series extending by successive gradations from monsters which are less than one complete individual, like the cyclops, through the normal individual to duplicate twins at the other extreme; and puts forward as a suggestion, rather than a conclusion, the theory that monsters which exhibit bilateral symmetry owe their development to causes inherent in the germ, and not to any pathological agency. While granting the abnormal character of monsters, he applies to the whole series, including the normal individual, the rather startling term of *cosmobia*, i. e., "orderly living beings." He thus aligns himself on the side of those who hold to a germinal origin of monsters.

The history of the specimen which I am about to describe is entirely unknown to me. It was given to me by Dr. H. B. Stone, of the Surgical Department, who found it stored in a jar in the University Dispensary while that building was undergoing repairs. The entire specimen had been placed in a solution of formaldehyde without any preliminary dissection or embalming, and consequently was not in good state of preservation. The body is that of a female foetus at or near full term, which on examination of the exterior presents nothing abnormal until the head is reached. Here, as the illustration shows (Fig. 1), there is only one eye, and that is median in position occupying the usual site of the nose; there is no evidence of an external nose or proboscis. Except for this absence of a rudimentary nose, the specimen is a typical cyclops, and could be placed between I and II of Wilder's series (Fig. 1 of Wilder's article). The cranium, it will be noted, is distinctly microcephalic, and the forehead low and rapidly receding.

The palpebral fissure measures 21 mm. in length, which is practically identical with a similar measurement of the fissure taken in

two newborn children. Close inspection of the margin of the lower lid reveals a small semilunar notch in the median line, on each side of which is a punctum lachrymale. Immediately behind the notch there is a small papilla in the fornix of the conjunctiva, doubtless a lachrymal caruncle. The dissection of the orbit discloses a cavity which is quite symmetrical bilaterally. Its floor is formed by an



orbital plate furnished by the two maxillæ, in which there is a median antero-posterior ridge indicating, possibly, a line of fusion; an infraorbital canal is present on each side. The roof is formed by an orbital plate furnished by the frontal, which bone lacks a median suture. The outer walls are formed in the normal way. In the median line of the floor just behind the infraorbital margin is a

small semi-spherical pit, which may be homologized with the lachrymal fossa. While the frontal bone lacks a median suture, there is in the median line a well-marked notch, which doubtless represents the nasal notch. There is complete absence, however, of the elements of the bridge of the nose, as well as of the lachrymals, ethmoids, and nasal fossae. The transverse diameters of the cornea and eyeball were found to be practically identical with those of the two newborn children. There is one lens, one iris; and the optic nerve is also single, entering the orbit through a median foramen at the apex. Of the other cranial nerves which enter the orbit it was quite easy to identify the stumps of the oculomotor, abducens, and ophthalmic division of the trigeminal left on both sides after removal of the brain; only the fourth pair could not be found. Within the orbit these nerves, unfortunately, were so badly preserved that I was not able to follow them to their destinations.

The muscles of the orbit, however, were in better condition, and I think that I was able to detect all that were present. These consisted of three pairs, as follows: 1. A pair of external recti, one muscle on each side of the ball, was easily identified. 2. A pair of inferior recti, below the optic nerve, one muscle on each side of the median line. 3. A superior pair, both of which were to the left of the median line and inserted into the upper aspect of the ball a short distance behind the cornea. In the absence of the nerve supply it did not seem possible to decide whether these should be considered superior recti, superior obliques, or one of each; if it were certain that the trochlear nerves were wanting, I should regard them as superior recti. No vestige could be found of an internal rectus, inferior oblique, or levator palpebrae.

The brain was in such poor condition that it crumbled to bits during removal. A fairly satisfactory inspection, however, could be had before removal, which showed plainly that the forebrain was badly crippled. The cerebral hemispheres were unpaired, and so rudimentary that the midbrain was uncovered; and the olfactory bulbs and tracts were entirely absent. The dura mater was thickened, measuring as much as 5 mm. in some situations.

In speculating upon the conditions underlying the production of

such a monster—and our imperfect knowledge of teratology forces us to speculate, in large measure—the condition of the brain seems to indicate the path to be taken in the present case. We may suppose that the course of events was somewhat as follows: At a very early stage of the embryo, before even the optic vesicles had begun to grow out from the brain, the embryonic forebrain was subjected to the action of some pathological agency which brought about an atrophy or destruction of the median portion of that vesicle of the brain, as a result of which the optic vesicles, instead of growing out as two anlagen, appeared as a single one median in position, unpaired yet containing potentially, at least, elements of both vesicles. In like manner the cerebral hemispheres made their appearance as a single, unpaired structure. The subsequent changes are susceptible of easy explanation. The median eye growing forward would come to preoccupy the place on the face normally taken by the nose, and the strong tendency of the embryo to bilateral symmetry would account for the other conditions. It does not seem necessary to invoke the fusion of two already formed optic vesicles here, though that process has occurred in some of the experimental work on cyclopia.

Thus the genesis of the cyclops described above would be undoubtedly pathological in nature; and the cyclopia would be, not a primary condition, but secondary to a defect of the brain. Consequently, according to Dr. Wilder's theory, it would not be entitled to be classed as a true teras (cosmobion). This brings up the question, Are we justified in thus excluding from the class of true monsters those bilaterally symmetrical ones which owe their production to pathological conditions? The fact that human cyclopic monsters always have crippled forebrains (Mall, *Study of Causes Underlying the Origin of Human Monsters*. Jour. Morph., Vol. XIX, No. 1, 1908) seems to negative the question. But, if it be answered in the affirmative, immediately another question suggests itself: What criteria, in fact, have we for the separation—where shall we draw the line of demarcation? The experiments of W. H. Lewis (Symposium on Experimental Embryology, Ass. of Amer. Anat., Baltimore, 1908) on fish embryos show that cyclopic monsters quite identical with those produced with magnesium chloride by Stockard

(Stockard, *Science*, Vol. XXVIII, No. 718, 1908) can be produced by simply removing a small area at the anterior end of the embryonic shield with a needle. It is quite conceivable that a pathological agent might thus act upon a minute area of the forebrain of a human embryo, and leave no trace behind save the cyclopia.

NOTE.—Since the above was written Dr. Stockard has published the complete account of his experimental work on the production of cyclopic fish monsters. (*The Development of Artificially Produced Cyclopean Fish*—"The Magnesium Embryo," *Jour. Exp. Zoology*, Vol. VI, No. 2, 1909.) His experiments show clearly, as do those of Lewis, that cyclopia can be induced readily by pathological agencies. There is, therefore, no necessity for assuming the hypothesis of germinal variation in the casual genesis of cyclopic monsters.

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No. 5

A PRELIMINARY NOTE ON THE NON-MEDULLATED NERVE FIBERS IN THE SPINAL NERVES.

BY

S. WALTER RANSON,

From the Anatomical Laboratory, Northwestern University Medical School.

It is an accepted dictum of neurology that the cerebro-spinal nerves (with the exception of the olfactory nerves and the nervus intermedius¹) consist almost entirely of medullated fibers, although it is admitted that a few non-medullated fibers, arising in the sympathetic system, pass into the spinal nerves along the gray rami communicantes. Experimental studies published during the last three years have cast doubt on the correctness of this conception of the spinal nerves.

In a paper on "Retrograde Degeneration in the Spinal Nerves"² it was shown that after division of a nerve containing 1500 medullated afferent fibers there occurred complete degeneration of 4500 spinal ganglion cells. Thus, three times as many cells disappeared as can be accounted for in terms of medullated axons divided at the time of the operation. But this extensive degeneration in the ganglion was accompanied by little or no degeneration in the dorsal roots. In order to find an explanation for these results a careful study of the literature was made and the results presented

¹Weigner. *Anatom. Hefte*, 1906.

²Ranson. *Jour. Comp. Neurol. and Psychol.*, vol. 16.

in another paper,³ which deals with the "Architectural Relations of the Afferent Elements Entering into the Formation of the Spinal Nerves." It was shown that the spinal ganglion consists chiefly of two kinds of cells, large and small. Although both types of cells are unipolar with T-shaped processes, they present a striking contrast in that the processes of the large cells are medullated while




FIG. 1.—Spencer Objective 2 mm. Eye-piece 8 ×. A single non-medullated fiber from a longitudinal section of one of the lower cervical nerves of a rabbit. Note the slightly irregular contour of the fiber and the small nucleus closely applied to it.

those of the small cells are destitute of myelin. The small cells are more numerous than the large ones, so that it becomes of interest to know what becomes of their non-medullated axons. Dogiel saw them divide in the same way as the medullated fibers and traced the central branches into the dorsal root and the peripheral branches to the point where the nerve is formed by the junction

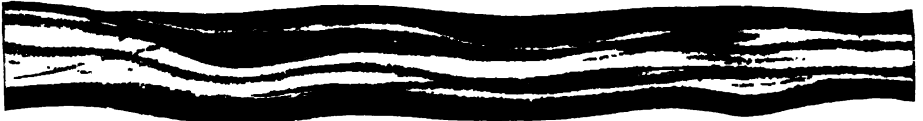


FIG. 2.—Spencer Objective 2 mm. Eye-piece 8 ×. A bundle of nonmedullated fibers from the sciatic nerve of the rabbit as seen in longitudinal section. Nuclei are associated with three of the fibers.

of the ventral and dorsal roots. As far as he was able to follow them they remained without a myelin sheath. That the peripheral branches do not end at the point of formation of the nerve from its roots, but pass on through the nerve, is indicated by another series of observations⁴ on the "Alterations in the spinal gang-

³Ranson. Jour. Comp. Neurol. and Psychol., vol. 17.

⁴Ranson. Jour. Comp. Neurol. and Psychol., vol. 19.

lion cells following neurotomy." After division of a spinal nerve nearly all of the cells in the associated ganglion show axonal reaction, although only the large ones are associated with injured medullated fibers. Moreover, the small cells are the first to react, show typical axonal reaction, and undergo complete degeneration. The natural inference is that the non-medullated axons of the small cells extend into the nerve.



FIG. 3.—Spencer Objective 2 mm. Eye-piece 4 X. An area of an oblique section through one of the lower cervical nerves of the rabbit. Note the light granular medullated fibers surrounded by a clear sheath and the bundles of dark nonmedullated fibers. The latter can be followed for some distance as they intertwine with each other.

These fibers have now been demonstrated in large numbers in the spinal nerves of the rabbit. In this work recourse was had to a modification of Cajal's method.⁵ Pieces of fresh nerve 5 mm. in thickness are placed for two days in absolute alcohol containing 1 per cent. of concentrated ammonia; washed 1 to 3 minutes in distilled water; placed for 3 to 5 days in a 1½ per cent. aqueous solution of a silver nitrate in the dark at 37 degrees C.;

⁵Azonlay. La Presse Medicale, vol. 13, p. 75.

washed 3 to 5 minutes in distilled water; placed for 1 to 2 days in a 1 per cent. solution of hydroquinone in 10 per cent. formalin. The tissue is then imbedded in paraffin and cut into sections which after mounting are ready for examination.

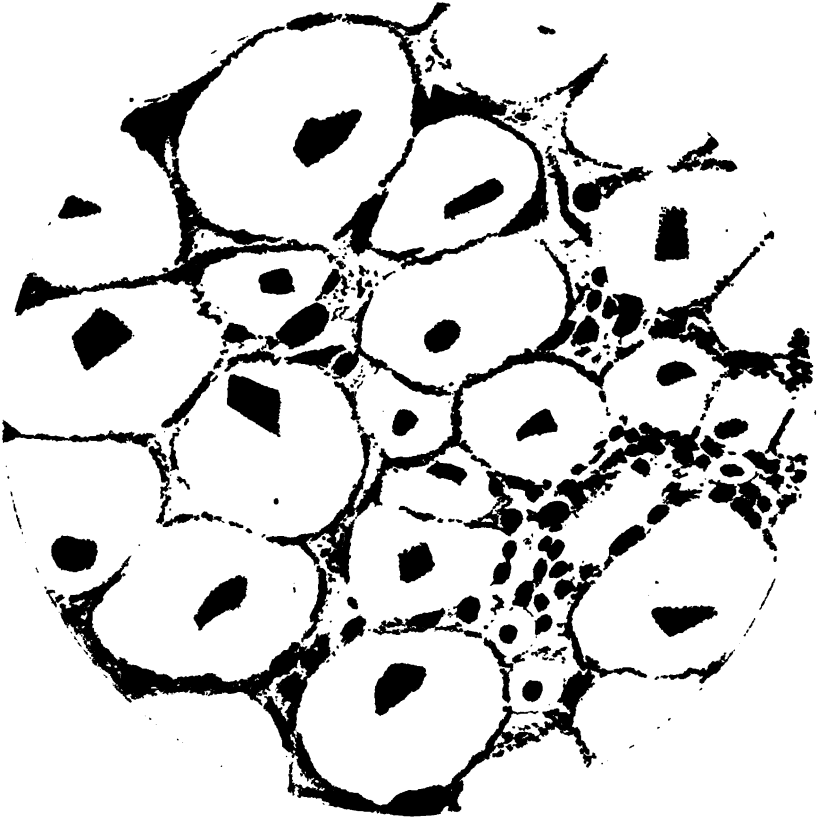


FIG. 4.—Spencer Objective 2 mm. Eye-piece 8 \times . An area of a cross section through the tibial nerve of a rabbit. The nonmedullated fibers are imbedded in the endoneurium in the interspaces between the larger medullated ones. They are much darker than the axons of the medullated fibers and are devoid of any trace of a myelin sheath.

The nerves of the white rat were found to be too small for satisfactory impregnation, but those of the rabbit gave good results. The sciatic, tibial, and lower cervical nerves were examined.

The preparations secured by this procedure show both medullated and non-medullated fibers. The former have a light yellow granular axon surrounded by a colorless medullary sheath. The non-medullated fibers are dark brown or black and do not present so granular an appearance. They vary considerably in size—some are as large as the smallest medullated axons, others much smaller. They lie in the interspaces between the medullated fibers directly imbedded in the endoneurium and not surrounded by anything resembling a medullary sheath. They show a pronounced tendency to group themselves into bundles, the individual fibers intertwining with each other. Sometimes a fiber can be seen to leave one bundle and pass into another. Because of their small size and compact arrangement into bundles very large numbers of them can lie in the relatively small interspaces between the medullated fibers. They are in fact more numerous than the medullated fibers themselves. Their distribution throughout the nerve, however, does not seem to be uniform. In cross sections their cut ends seem much more numerous in certain parts of the section than in others. It is often possible to demonstrate a nucleus lying along the fiber in immediate contact with it, apparently belonging to a thin neurilemma.

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VARIATIONS WITH DISTENSION IN THE WALL AND EPITHELIUM OF THE BLADDER AND URETER.

BY

RICHARD W. HARVEY.

From the Anatomical Laboratory of the University of California.

WITH 5 FIGURES AND 1 TABLE.

For some years during the usual class work in histology in this laboratory, comparisons of the distended bladder epithelium with that in the contracted state have given rise to the impression that in the thinning consequent to distension, the cells of the epithelium were not only flattened, but also were to some extent actually displaced from their relative positions. This impression has suggested this paper, the purpose of which is to describe some variations in the wall, and in the epithelium alone, of the bladder and ureter occurring with their distension.

Material and Methods.—The bladder and the attached ends of the ureters were removed from a freshly killed dog. A portion of the bladder was tied off so that the fluid used in distending the remainder could not enter it, and ligatures were applied to the ureters close to the bladder. Then, by means of a large syringe, Zenker's fluid was forced into the bladder, by way of the urethra, until it attained about the condition of maximum normal distension with urine and a ligature was applied to retain the fluid. The distended bladder, together with the contracted portion which had been tied off, were then immersed in Zenker's fluid, and, of course, became fixed in the condition in which they were when immersed. A piece of one of the ureters about four inches long was removed, and a ligature was applied about its middle. Into one end, the syringe, filled with Zenker's fluid, was inserted, a ligature loosely applied and then a pressure of the syringe was applied until no further extension was possible. The syringe was then removed at the same time that the ligature was tightened. The thus distended portion

of the ureter, together with the contracted portion, was then immersed with the bladder in Zenker's fluid for complete fixation.

Pieces for study were cut from the contracted and distended bladder and ureter, washed, dehydrated carefully and embedded in paraffine. In cutting the sections, care was taken to cut perpendicular to the surface of the epithelium. The sections were stained in haematoxylin and congo red, the latter being chosen as the counterstain because of its efficiency in bringing out cell boundaries.

Variations in the Wall of the Bladder.—Measurements were taken of the entire wall of the bladder in the contracted and distended conditions, the averages in micra being recorded in Table 1. A comparison of these results shows that the thickness of the entire wall in a distension about equal to the condition of maximum normal distension with urine, is about one-tenth that in contraction, or decreases 90.7 per cent. with distension.

The thickness of the muscularis in distension is about one-twelfth that in contraction, or it decreases 92 per cent. with distension. The muscle fibres of the bladder are very much extended during distension. In extreme distension the amount of thinning is aided by the power of distension of the connective tissue to which the muscle fibres are attached. The bladder wall, therefore, with regard to its connective tissue component, at least, is in part like a true elastic membrane in extreme distension, in that, to a certain extent, it relaxes of its own elasticity.

Distension of the tunica propria of the bladder, under the same pressure, of course, as the muscularis, reduces its thickness to one-fourth that in contraction, or it decreases 74 per cent. with distension. The difference between the variation of the tunica propria and that of the muscularis is probably accounted for by the fact that during the later stages of contraction of the bladder, tunica propria is thrown into folds along with the epithelium.

Variations in the Wall of the Ureter.—In one respect is the distension of the wall of the ureter quite different from the distension of the bladder wall. The distensibility of the bladder has no definite limit. Pressure exerted will gradually and continuously distend

the bladder until its walls become so thin as to burst, so great is the elasticity of the connective tissue. The distensibility of the ureter is more limited. In distending this, a point is reached at which considerably greater pressure than that used with the bladder fails to further distend it, a definitely fixed limit of distension becoming very apparent. This is indicated in Fig 1. A, of this figure, shows the relaxed ureter with the characteristic folds in its epithelium and tunica propria; B, shows the ureter fixed under extreme distension from the application of pressure probably suf-

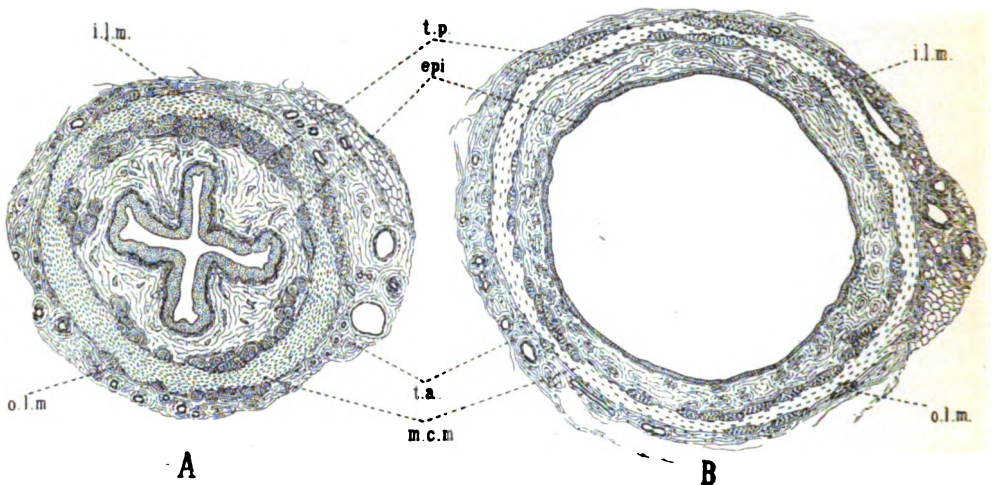


FIG. 1.—Drawings of A, contracted and B, distended ureter showing limits of distensibility. The two are drawn to scale; epi., epithelium; t.p., tunica propria; i.l.m., inner longitudinal muscle layer; m.c.m., middle circular muscle layer; o.l.m., outer longitudinal muscle layer; t.a., tunica adventitia.

ficient to burst the bladder wall. The arrangement and abundance of the supporting tissue, and the more organized arrangement of the muscular investment of the ureter, undoubtedly account for the difference between it and the bladder.

Measurements were taken of the entire wall of the ureter, as in the case of the bladder, in the contracted and distended conditions, the average in micra being recorded in Table 1. Comparing these results it is shown that the thickness of the entire wall of the

ureter in contraction is two and three-quarter times that in distension, or the thickness of the wall is reduced 63.7 per cent. by distension, instead of the corresponding decrease of 90.7 per cent. in the case of the bladder wall.

The distended muscularis of the ureter is about one-half as thick as in contraction, or the muscularis is reduced 56 per cent. in thickness by distension, instead of 92 per cent., as was that of the bladder. The distended tunica propria is likewise about one-half

TABLE 1.

		Thickness of Entire Wall		Thickness of Muscularis		Thickness of Tunica Propria		Thickness of Epithelium		Layers of Nuclei	
		Micra	Per Cent. Decr.	Micra	Per Cent. Decr.	Micra	Per Cent. Decr.	Micra	Per Cent. Decr.	Number.	Per Cent. Decr.
Bladder	Contr.	5236.1		4762.8		301.2		172.0		4.37	
	Dist.	486.4	90.7	382.8	92.0	76.0	74.7	27.6	84.0	2.25	48.5
Ureter	Contr.	751.3		243.4		239.4		268.5		7.67	
	Dist.	272.6	63.7	108.0	55.6	116.8	51.2	47.8	82.2	4.00	47.8

TABLE 1.—Recording, in micra and percentages of decrease, variations in thickness of the wall, and variations in number and percentages of decrease of the layers in the epithelium of the dog's bladder and ureter in the contracted and distended conditions.

as thick as in contraction, undergoing a reduction of 51.2 per cent. in distension. The close approximation of these variations in the muscularis and tunica propria of the ureter is probably accounted for by the fact that contraction of the ureter does not result in such extensive folds in its tunica propria and epithelium as occur in the contracted bladder, where the difference in the variation of muscularis and tunica propria is about four times as great as that of the ureter. The average thicknesses in micra of the muscularis and tunica propria are recorded in Table 1.

Variations in the Epithelium of the Bladder and Ureter.—The contracted bladder epithelium has the appearance illustrated in Fig. 2. The arrangement consists of a basal layer (a) of cubical cells resting on the tunica propria; a middle layer (b) composed of approximately three layers of irregular, polygonal, or elongated cells; a superficial layer (c) of large ovoid cells from whose under surfaces processes fit into the interstices between the cells of layer (b). The nuclei are full and spherical and the cell boundaries fairly distinct.

Variations in Thickness.—Measurements taken of the epithelium of the bladder in the contracted and distended conditions show that

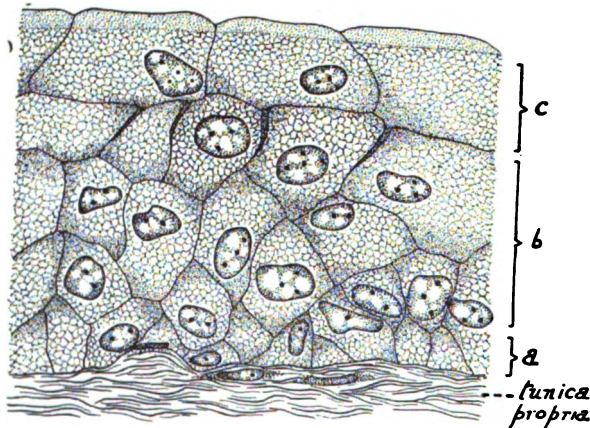
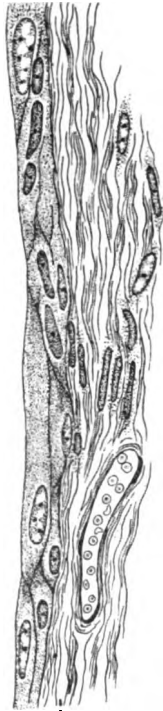


FIG. 2.—Contracted bladder epithelium, drawn with camera lucida. $\times 750$.

the thickness in distension is about one-sixth that in contraction, or that it decreases 84.0 per cent. with distension. Measurements of the ureter show that the thickness of the epithelium in distension is between one-fifth and one-sixth that in contraction, or that it decreases 82.2 per cent. with distension (see Table 1). Comparing these measurements, there is a difference between the two in percentage decrease with distension of only 1.8 per cent. Thus while the distension results in approximately the same degree of distension in the epithelium of the two organs, the effects are noticeably greater on the muscularis and tunica propria of the bladder than on the correspond-

ing parts of the ureter. This difference between the two is explained as due to the fact that the bladder is capable of, and customarily undergoes, greater extension than the ureter and, when fully contracted, its epithelium is thrown into larger and more extensive folds than that of the ureter. The similar effect upon the epithelium of the two is of interest as indicating a probable proportional arrange-



tunica propria

FIG. 3.—Distended bladder epithelium, drawn with camera lucida. $\times 750$.

ment of the different coats protective against stretching the epithelium to an injurious extent.

In the distended condition, the bladder epithelium appears as in Fig. 3. The basal layer is so flattened that it is somewhat confused with the connective tissue cells of the tunica propria. The middle layer is represented by a few straggling nuclei; and the superficial

layer is greatly elongated and flattened, the interstitial processes being nowhere in evidence. The nuclei are greatly elongated and flattened, and the cell boundaries of only the superficial cells are found distinctly evident throughout. Elsewhere the boundaries appear discontinuous and in fragments, as though the cytoplasm of adjacent cells has fused in places, or distension has rendered the membranes so thin as to be invisible.

An observation of the arrangement of the nuclei was found useful

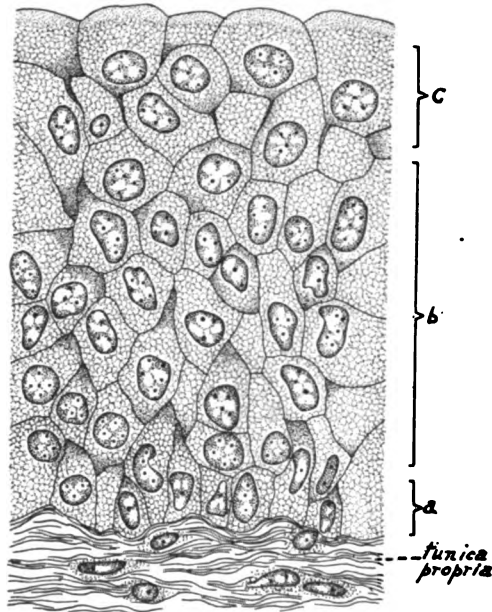


FIG. 4.—Contracted ureter epithelium, drawn with camera lucida. $\times 750$.

in the study of the structure of the epithelium. This observation was made by counting the nuclei lying in the same focal plane from the basal to the superficial layer. The results of counts taken in different regions of the bladder under the same conditions of contraction and distension are recorded in Table 1. It will be seen that distension reduces the number of rows of nuclei 48.5 per cent, or approximately one-half.

The epithelium of the ureter is of the transitional type, but

relatively thicker in the contracted state than that of the bladder, and disposed in more constant folds, Fig. 1, A. In the contracted state, three layers, comparable with those of the contracted bladder epithelium, are defined, Fig. 4. However, the middle layer is composed of at least five rows of cells as compared with three rows in the middle layer of the bladder epithelium.

The distended ureter has the appearance of Fig. 5. In this condition the folds are lacking, the epithelium is greatly compressed, and the cells and cell-nuclei greatly elongated.

As in the case of the bladder, a comparison of the two conditions shows the number of layers of the epithelium to have been diminished through distension 47.8 per cent, or approximately one-half. The average results of the counts of nuclei lying in the same focal plane between and including the basal and superficial layers in differ-

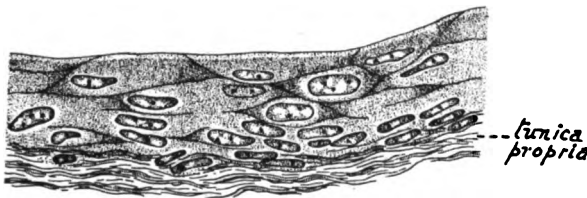


FIG. 5.—Distended ureter epithelium, drawn with camera lucida. $\times 750$.

ent regions of the epithelium of the ureter, under similar conditions of contraction and distension, are recorded in Table 1.

Comparing the percentage decrease of the layers of nuclei in the epithelium of the distended bladder and ureter shows a difference of only .7 per cent. The approximation of this result to the 1.8 per cent difference in decrease of thickness of the epithelium of the bladder and ureter due to distension, indicates a relatively equal distension of the two organs.

By comparing the variations in the epithelium of the bladder and ureter, it is seen that the thickness of that of the bladder decreases 84 per cent, with distension or about one-sixth of its thickness in contraction, while the layers of nuclei in vertical section decrease only 48.5 per cent, or to about one-half the layers in contraction, and that

the thickness of the epithelium of the ureter decreases 82.2 per cent with distension, or to about one-fifth the thickness in contraction, while the layers of its nuclei decrease 47.8 per cent, or likewise to about one-half the layers in contraction. If cells are only flattened or spread out by distension, then, to be decreased in vertical thickness to one-sixth or one-fifth of its thickness in the contracted condition, as is the entire epithelium, each cell, on the average, would be flattened out to extend over an area five or six times as great as in the contracted state. This would result in a large number of non-nucleated, thin edges of cells in the sections. Such were described by London, but were not observed in this investigation.

An examination of the literature shows that Paneth ('76) followed a series of changes in the bladder epithelium of the dog resulting from different degrees of distension. He described in the contracted bladder the usual three layers of the epithelium, viz., a superficial layer of broad, thick cells, each overlying several of the cells beneath; a middle layer composed of polygonal or trumpet or tooth-like cells in several layers, and a basal layer composed of more or less cubical or cylindrical cells; and he observed that as the bladder was distended, the cells became flattened, until in the fully distended bladder the epithelium resembled the stratified pavement type. However, he recorded no measurements of the variations nor observed them in much detail.

London ('81) investigated the bladder epithelium of the dog under different conditions of extension, and reached the obvious conclusion that the volume of a single cell, whether contracted or distended, remains the same. He remarked, that, in contraction, the bladder epithelium consisted of five layers of almost cylindrical cells, while in extreme distension it consisted of apparently only one, a layer of flat cells. He accounts for this variation by the supposition that the apparent diminution in layers relates only to the layers of nuclei, that these latter are pushed widely apart by distension, and the flattened cells really exist in their same relative arrangement, but appear as fine lines in section. He concluded, then, that there is no loss of coherence such as would result from a slipping of the cells of one layer between those of the neighboring layers in distension,

but merely a flattening of the cells of each layer into thin plates. He disregarded the layers of nuclei as indicating the layers of cells. He further reached a rather peculiar conclusion that, while the return to the normal after distension is devoid of any alteration in previous relation and arrangement of parts, just as in an elastic membrane, in one particular the behavior of the bladder epithelium is different, namely, that the epithelium of the emptying bladder possesses a greater elasticity than that of the filling bladder.

Dogiel ('90) claimed that protoplasmic processes bind the cells of one layer to those of another, and Eggeling ('01) described the superficial cells closely applied to the underlying cells with processes extending between the latter.

Herzog ('04), contrary to London, made use of the occurrence and arrangement of nuclei for a study of the layers of the epithelium of the urethra, when under different conditions.

In the preparations used here, the lines interpreted by London as cell boundaries and as representing the thinned edges of flattened cells were not observed, and congo red is considered one of the best counterstains for bringing out cell boundaries.

It is here suggested as possible that in distension, besides the flattening and elongation of the cells due to compression, there is an actual displacement, not only of the cell nuclei, as concluded by London, but also of the cells themselves. An examination of the sections of distended bladder and ureter shows numerous cases of the apparent displacement of the cells of the superficial layer. In Figure 3, for example, there is an indication that adjacent superficial cells have been separated and so that the immediately underlying cells of the middle layer are exposed to the surface. The epithelium, by being thrown into folds during contraction, is evidently allowed to relax more gradually than the muscular wall, and, if such is necessary, a gradual resumption of the former relations of the cells to one another is possible.

Dogiel ('90) pictures a bit of dissociated epithelium from the bladder of the white mouse, stained with picro-carmin, showing filaments establishing actual protoplasmic continuity between the larger superficial cells and the cells of the subjacent layer, and claims

the continuity thus indicated is a normal relation between the cells. Numerous areas of both partially and totally dissociated cells were to be observed in the folds of the epithelium of the contracted bladder used here, but no protoplasmic filaments as described by Dogiel could be discerned, other than such as could be more safely explained as products of maceration. When maceration is less extensive, though the superficial cells are completely separated (and numerous cases of such could be seen in the preparations), the cells of both layers show smooth boundaries, the superficial layer having only the processes mentioned above as extending between the cells of the subjacent layer. Even these latter processes were absent in the distended condition, the cells having a smooth boundary throughout. Only in manifestly extreme maceration could irregular and finely ragged borders be seen. Zenker's fluid was used for fixing here, directly applied, while Dogiel used Müller's fluid and stained with picrocarmine. Congo red was used here and this, as a cytoplasmic stain, is far more efficient for fine processes than is picrocarmine.

CONCLUSIONS.

1. Comparative measurements of the entire wall of the dog's bladder and ureter in approximately the same degree of contraction and in distension by approximately the same pressure show that the thickness of the bladder wall is decreased considerably more than that of the ureter.
2. The extent of distensibility of the ureter is more definitely limited than that of the bladder, undoubtedly due to the more organized arrangement of the supporting tissue and muscular investment of the ureter.
3. The relative effects of distension are much more evident in the muscularis and tunica propria of the bladder than in these tunics of the ureter, while the thinning effect of the distension upon the epithelium of the two is approximately the same, due to the fact that, in the later stages of the customary contraction of the bladder wall, the epithelium is thrown into more extensive folds than that of the ureter, for, during distension, these folds must first be obliterated before the thickness of the epithelium is much affected by distension.

4. The epithelium of the ureter is thicker in the contracted state than that of the bladder, but, approximately normal maximum distension produces in the epithelium of both approximately the same percentage of reduction in thickness (about 80 per cent) and approximately the same percentage reduction in the layers of nuclei (about 50 per cent) in both.

5. It is suggested that the diminution in the layers of nuclei may possibly indicate, not only the spreading of the epithelial cells resulting from distension, but, that to some extent at least, in the process of compression, the cells may glide upon one another or be slightly displaced as the epithelium decreases in thickness.

In conclusion acknowledgments are due to Professor Hardesty, at whose suggestion and with whose guidance and advice this investigation was undertaken.

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BOOK REVIEWS.

QUAIN'S ELEMENTS OF ANATOMY; Eleventh Edition; Vol. III, NEUROLOGY; PART I, The General Structure of the Nervous System and the Structure of the Brain and Spinal Cord. Edited and Revised by E. A. Schäfer and J. Symington, with Index by T. W. P. Lawrence. 421 pages and 361 illustrations. Royal 8vo. Longmans, Green & Co., 1908. \$4.50.

The many friends of Quain's Anatomy are delighted that the work is being again revised. Volume I, *The Embryology*, the first of this, the Eleventh Edition, was issued by the publishers earlier in 1908 and has met much of the approval deserved by the editors for the current information it incorporates and for the retaining of that concise comprehensiveness of treatment characteristic of the previous edition. The second text issued of this revised edition is Part I of Volume III, *Neurology*, and in this part the preceding standard of excellence is maintained.

Part I, of Volume III, embraces the general structure and briefly considered processes of development of the nervous tissue elements, and is chiefly devoted to the gross and microscopic structure of the central nervous system. While it necessarily treats of their central connections in considerable detail, this part does not include the Anatomy of the Organs of Special Sense. The promise is made that it will be soon followed by Part II, which will embrace the descriptive and special anatomy of the sense organs and of the peripheral nerves in general. The two parts together will constitute Volume III, a complete Text-book of Neurology.

In the present revision of the Neurology, Professor Schäfer, the chief editor of the previous edition, has associated with him Prof. Johnson Symington of Queen's College, Belfast. Professor Symington was editor with Professor Schäfer of the *Splanchnology*, Part IV of Volume III of the Tenth Edition, and his name now appears as well in the title page of *Embryology*, Vol. I, of the present edition.

The part is edited and in considerable measure rewritten and

there is added a large number of illustrations not contained in the previous edition. The result is a book exceeding the previous "*Spinal Cord and Brain*" by some two hundred pages. Acknowledgment is made to authors who gave permission for the use of their illustrations and especially to Professor Cajal who, in addition, loaned many original drawings for reproduction in the work.

One of the most striking features of the book is the large proportion of microscopic anatomy it contains. The first 57 pages, after giving an introductory survey of the general structure and mode of development of the entire nervous system, are especially devoted to the histology or detailed consideration of the structural elements of the system, including the forms of nerve terminations, the process of degeneration and regeneration, and a couple of pages upon the methods by which nerve pathways are traced. And, throughout the remainder of the text, a large proportion is devoted to microscopic details of the architecture of the system. This excess of the microscopic is one of the features which has contributed toward the peculiar favor in which Quain's Anatomy has been held by many teachers and students. Were the microscopic eliminated to the extent it is in any of our large, one-volume, text-books of Anatomy, the neurology of even this edition of Quain would scarcely exceed, in pages, the text generally devoted to the subject in any of the better of these other works. On the other hand, the part does not attempt to be as exhaustive a treatment of the neurology as is given in the special works on the subject. It is not so full as the latest edition of Edinger's Lectures on the central nervous system, but, as a text-book for general class use rather than a reference book, its construction will lead many to prefer it to Edinger.

In treating the cerebro-spinal axis, it follows the usual and most advisable plan of beginning with the spinal cord. Thence it passes to the medulla oblongata and pons, taken together, followed by the study of the cerebellum. Then the mesencephalon, diencephalon and telencephalon are taken up in their order, followed by discussions of the development of the cerebral gyri, sulci and fissures, the meninges, the blood supply, measurements of the brain, and cranio-cerebral topography. The final 47 pages are devoted to an excellent

treatment of the intimate structure of the hemispheres and especially that of the Rhinencephalon, to which latter alone about 17 pages are devoted. The sequence is excellent for teaching purposes as well as the generally followed plan of proceeding from the gross to the microscopic structures of the different divisions.

The mesencephalon is classed as not a division of the cerebrum, being described as "a short and constricted part of the brain uniting the pons and cerebellum below with the cerebrum above."

At the end of the discussion of the development and causation of the gyri and sulci of the hemispheres, Professor Symington has inserted 10 pages comparing the size and gross features of the cerebral hemispheres of the Primates. Brains of the Marmoset, Capuchin monkey, Bonnet monkey, Baboon, Gibbon, Orang, Chimpanzee, and Gorilla are described in the order named, compared among themselves and with the human cerebrum. This is a commendable and most interesting addition to a treatment of the human brain and made by one especially qualified for it. His illustrations of the different hemispheres are most excellent.

The treatment of the cerebellum is enlarged by several pages, is comprehensive and sufficiently detailed as to gyri, sulci and microscopic structure, and includes a number of new and excellent illustrations by the editors and from Cajal.

The text upon measurements and weights of the brain is altered much less than might be expected, considering the information accumulated upon this subject since the appearance of the tenth edition.

The section on Cranio-cerebral Topography comprises nine pages with three new, full-page figures, and is a brief, up-to-date treatment of the subject. A separate discussion of this subject was not included in this part of the tenth edition at all.

The general description of the neuroglia is not all that might be desired. The neuroglia fibers are spoken of as numerous offsets of and in continuity with neuroglia cells, when, in fact, a large proportion of the neuroglia fibers of the adult nervous system have ceased to be in contact with neuroglia cells and none can be considered as offsets of them any more than the fibers of other forms

of fibrous connective tissue can be considered offsets of the connective tissue corpuscles. Further, the custom is retained of considering and classifying as neuroglia cells the various pictures of neuroglia obtained by the Golgi method, when it is more than probable that many of these accumulations of the silver deposit contain neither cytoplasm of neuroglia cells nor even a nucleus.

The editors, Professor Symington especially, have added quite a number of new illustrations of the macroscopic features, all of which possess excellent teaching qualities. Most of the drawings selected from the work of other authors are taken from one author alone. Of the total of 361 illustrations in the book, about one-third are from Cajal and most of these are from Golgi preparations. From the fact of the very limited accuracy and completeness of the results of the Golgi method, it might be urged that so great a proportion of Golgi pictures, though taken from an author so pre-eminent in authority and in the use of the method, is not advisable for a text-book. The diagram, Fig. 150, shows no ascending portion of the sensory root of the Trigemini, though Fig. 171, which is from Cajal, shows such to exist. Fig. 137 is a little misleading in its claim to be of the natural size of the floor of the fourth ventricle.

The BNA is used, translated into English and untranslated, but by no means consistently throughout. This will please some, but many will consider the limited use of the nomenclature as unnecessarily conservative at this stage of its adoption. A bibliography is given, but, unlike the plan followed in the previous edition, the citations are placed at the foot of the pages referring to them and thus where they will be more usually noted and more frequently used by the student.

The press work of the book is good and the size of the paper and the type, as well as the general style in which it is written, are the same as of the tenth edition. On the whole, one is impressed with the very copious illustrations and the construction of the text, but, after looking it over carefully, one feels a bit disappointed with it as a part of a newly revised edition of *Quain's Anatomy*.

Irving Hardesty.

Received for publication, January 28, 1909.

DOGIEL, A. S. *Der Bau der Spinalganglien des Menschen und der Säugetiere.* Jena, G. Fischer, 1908. 151 pp., 14 plates.

The results of more than ten years of careful research upon the spinal ganglia are embodied in this beautiful monograph. The author, after successful experience with the silver nitrate methods of Cajal, decided that the methylene blue method with which he has already had so much experience gives more valuable pictures of the structure of the ganglia. Accordingly, most of the paper is devoted to the description of such preparations. Most of the anatomical findings of Cajal, Levi, Lenhossék, Nageotte and others are confirmed and supplemented, with, however, some differences of interpretation.

The preparations described and figured by Dogiel are of remarkable beauty and the complexity of ganglionic structure which he brings to light is bewildering. No attempt can be made in this review to summarize the characteristics of the eleven types of spinal ganglion cells described; the original should be consulted by all who are interested in ganglionic structure, either from the anatomical physiological or clinical points of view. These findings have important applications in all of these fields, as well as to the general theories centering about the neurone concept.

Each spinal ganglion cell is surrounded by a capsule which is a fine homogeneous structureless membrane usually stained in methylene blue preparations. External to the capsule is a loosely fibrous connective tissue sheath, containing many nuclei, some of which are often closely attached to the outer surface of the capsule. These are all ordinary connective tissue nuclei. The sheath is more extensively developed in those types of cells in which the chief process or dendrites of the ganglion cell arborize in the immediate vicinity of the parent cell. Enclosed within the meshes of the connective tissue sheath are often found some of the complex termini of processes of the ganglion cells; the glomerulus of the chief processes may lie within it, and also the elaborate sympathetic plexus described in the later sections of the paper.

Amongst the numerous types and subtypes of ganglion cells de-

scribed, the familiar unipolar cells with T-shaped processes occupy a quite subordinate position. Usually the neurone is far more complex than this. Cells giving rise to these simple T-fibers (type I of both the older and the present classification of Dogiel) are of all sizes from the largest to the smallest, and seem to be less numerous than some of the more complicated types.

The variations of the remaining ten types are infinitely diverse. Sometimes the chief process divides into a skein or network of branchlets, within or without the connective tissue sheath, all of which reunite to form a single process which later divides T-form in the usual way (types V, VI, VII). Or collaterals may be given off from the chief process with the most diverse sorts of endings. Some of these have swollen tips which end either within the connective tissue sheath or outside of it, sometimes at great distances from the parent cell. In the latter case the mode of ending is very diverse (types II, III, IV). There are also bipolar cells of the embryonic type, with two simple processes, one of which is central, the other peripheral (type IX). Or the chief process may divide T-form into central and peripheral branches, the latter breaking up into an extensive arborization which ends within the ganglion or its dorsal root, but does not reach the periphery (type VIII). Again, in addition to a chief process of typical T-form, as in type I, there may be one or more thick, short processes (dendrites) which break up within the connective tissue sheath of the cell (type X). These are cells of small size with the chief process unmedullated and the author regards them as immature cells in process of differentiation into functional neurones of other types.

Finally, there are multipolar cells of very peculiar form, not hitherto described (type XI). There are several processes, one of which is a typical chief process like that of type I. The others leave the connective tissue sheath, generally become medullated, divide within the ganglion and end in special free or capsulated endings variously distributed within the ganglion, chiefly about its periphery. These dendrite-like branches are regarded as the peripheral processes; but they end within the ganglion or in its immediate neighborhood. They seem to be sensory nerves for the ganglia and their

connective tissue envelopes. The chief process does not divide T-form, but is thought to pass directly into the spinal cord as a central process.

The spinal ganglion is filled with medullated and unmedullated fibers which arise in large part from the cells of the ganglion itself and which end free or in expanded tips or encapsulated endings within the ganglion and the dorsal root and particularly in the connective tissue envelop of the ganglion and the septa within it and the connective tissue capsules of its cells. These endings and fibers are of very diverse forms. Some of these fibers before ending wind spirally around the chief process of a type I cell. Sometimes several fine fibers enter into the formation of such a spiral.

Dogiel is of the opinion that the free and encapsulated endings in the spinal ganglia are for the most part sensory organs, thus differing from Cajal and Nageotte, who regard them, especially the expanded endings, as growing nerves analogous with the expanded tips of regenerating nerves. Dogiel gives many reasons against this; for example, these endings are similar to many familiar types of peripheral sensory endings. If Cajal is right, these, too, would have to be regarded as regenerating or growing terminals.

In general, then, the spinal ganglia of all of the mammals investigated show intra-ganglionic sensory endings which in some cases seem to be termini of ordinary peripheral branches of the T-form division of the chief processes of the ganglion cells; in other cases they are termini of special dendrite-like processes of the ganglion cells. These endings are sometimes capsulated, constituting varieties of the Vater Pacinian (Golgi-Mazzoni) corpuscles; others are free, forming varieties of free end-skeins similar to those found in the nerve termini at the periphery.

The preceding types of fibers all arise from cells of the spinal ganglion. Other fibers enter the ganglion from the outside. The source of some of these fibers is obscure; but some of them undoubtedly come from the sympathetic system. The latter come in by way of the rami communicantes; they are partly medullated and partly unmedullated, but are all small fibers. Every spinal ganglion cell (including all of the types) is probably enveloped by

a network of fine sympathetic fibers. These pericellular nets are all connected and bound up in a common network which pervades the whole ganglion. This network lies in the connective tissue sheath of each cell, not under the capsule.

Dogiel's monograph is accompanied by eighty-nine exquisite figures drawn by the author and based, with one exception, on preparation from the horse, which, together with the lucid and well-arranged text, make the work unusually clear and easily read, in spite of the complex nature of the material.

C. Judson Herrick.

Received for publication, February 27, 1909.

ECONOMIC ZOÖLOGY, an introductory text-book on zoölogy, with special reference to its applications in agriculture, commerce and medicine. By Herbert Osborn. The Macmillan Co. 1908.

The scope of this work is sufficiently indicated by its title and by a statement, in the preface, of the author's hope that beyond being a mere text-book, "it may be of service to that ever-increasing body of citizens who wish to familiarize themselves with the general principles and the present status of knowledge concerning the animal kingdom."

The introduction, of nine pages, is, in the opinion of the writer of this review, open to certain criticisms from the pedagogical standpoint; first because it does not present an adequate setting for such a discussion of the Protozoa as is given in Chapter II; and second, because of the examples of a kind of pedagogy of which there are many instances at other places throughout the book. For instance, on page 7 the following sentence occurs, "Locomotion, however, is connected with a great variety of structures, among which may be mentioned pseudopodia, cilia and flagella of protozoa; the parapodia and setae in worms; the swimmerets and legs in crustacea; legs and wings in insects, and fins, legs, paddles, wings, etc., in vertebrates." Over half of the terms used in the foregoing sentence are technical ones and indicate things which the elementary student cannot reasonably be expected ever to have seen or to have any conception of, and thus the sentence does not convey any clear picture of what it is in-

tended to call before the student's mind, namely, the diversity of the organs by which locomotion is effected in the animal kingdom as a whole. The writer is aware that this kind of description is common in zoölogical text-books, but its commonness certainly does not justify such a method and it is quite contrary to the method which his own experience tells him is likely to fasten such matters in the mind of a student. Taking this example as a text and the further instances of the use of the terms "cell," "protoplasm," etc., upon page 6, without any previous explanation of what these terms mean, we may say that this way of presenting zoölogy, or any other subject, is distinctly putting the cart before the horse. In our experience, students are not impressed by words which convey either no meaning at all or only the hazy conceptions of the public at large. If such a thing as locomotion is to be discussed, the way to present it, and have the presentation take root, is to let the students first study along with other things, the structure and function of the locomotor organs in a series of animals and then to set before them such statements as are desirable regarding locomotion in general, using as illustrations the cases studied. If one wishes to talk about the cell or protoplasm to a body of students, having no previous training in biological science, the method of procedure should be likewise by a description of the thing itself, followed by the name and last of all the generalizations. This way of presenting things is, in the opinion of the writer, a habit of thought which is as necessary for the more advanced as for the elementary teacher, but which with more mature students can, of course, be somewhat compensated for by the better trained perceptions of those to whom the instruction is being given. The writer realizes how difficult a thing is an introduction and he would not have so much fault with this one, provided the thing introduced did not begin in such a manner as to make the preceding nine pages a wholly incomplete setting for the subject as it is handled in the chapters on the protozoa and the groups which follow.

In the second chapter, which deals with the phylum Protozoa, we find again examples of the use of technical terms such as "cells," "protoplasm," "germ layers," "chromatin granules," "gastrula," "ectoderm," "endoderm" and "cilia," with no previous explanation

of their precise significance. As examples of a careless use of words and facts there may be cited the statement at the top of page 13, "the *Amœba* possesses locomotion, nutrition," etc., and on page 20 the statement, regarding the Sporozoa, that "this group includes the parasitic protozoa," as though no other protozoa except the sporozoa were parasites. Or again in this sentence, on page 29, "Calkins has shown experimentally that without this process of conjugation there is in time a deterioration of the *Paramœcium*, as indicated by its rapidity of growth, ability to multiply by fission and other activities;" and by the statement that the malaria parasite is an "amœba-like species." Taken as a whole, there is little to commend this chapter on the protozoa and it is particularly weak as the first concrete chapter of a course in the fundamentals of zoölogy. The third chapter, which is entitled "Sponges, Hydroids and Polyps," is again characterless and shows an apparent ignorance of many important facts in sponge embryology, most of which were well established ten years ago, when the statement is made upon page 37 that the cell layers of sponges "are formed in the same manner and occupy the same position as in all the higher groups of animals," and further on that "perhaps the most striking fact is found in the uniform invagination and formation of the gastrula in sponges and all other metazoa." The chapter upon the flat-worms deals for the most part with the parasitic members of this phylum. The accounts of the structure and life history of *Taenia solium* and of the liver-fluke are good, though there is nothing in them which is not common to a number of text-books now in use and they thus lack distinctive merit. The few pages, with figures taken from U. S. Department of Agriculture Reports and dealing with forms less frequently described, are an addition to this subject, not commonly found in our texts, and hence of greater value than what precedes them. The chapter upon the round-worms might have been enlivened by some really good illustrations and the brief discussion of "the effects of parasitism," is not nearly so extensive as might well have been given this general topic after an account of the parasitic worms. Two chapters dealing with the Annelids and Molluscoida are again without any degree of freshness or obvious merit and the chapter upon Echinoderms is, in

the writer's opinion, distinctly bad, because of its descriptions of structures with no accompanying references to figures and the discontinuity of the style and thought. Indeed, some of the sentences on page 134 read like the blue-books of the elementary students for whom this text was intended. As an example of the inverted order of pedagogy previously mentioned, we may cite the paragraph upon page 139 regarding the evolutionary history of this group, and, as a whole, the chapter shows no great familiarity with the facts of echinoderm anatomy and embryology. The chapter upon the Mollusca has some merits and a larger proportion of new figures than most of the others, but these, however admirable they may be as the drawings of undergraduate students, are in the case of those dealing with *Lampsilis luteolus* of scant value for a text-book. The Crustacea are again not dealt with in any unusual manner and the chapter devoted to this group is open to the kind of criticism already made.

Chapters XI, XII and XIII dealing with the Arachnida, Proto-tracheata and Insecta and comprising 106 pages are however distinctly valuable and to be commended in a book of this nature and if the remainder of the book were of the same quality it would have a far greater merit as a whole. The numerous illustrations from Department of Agriculture publications are a valuable source of reference and the author's special preparation in this line is at once evident. With the Chordata, however, the same things which constitute the defects of the earlier chapters reappear, though with the birds and mammals the treatment is less open to criticism, and the concluding chapter of "General Considerations," the only one, by the way, which deals with the facts of zoölogy in any other manner than from the standpoint of the single group, brings nothing to relieve the monotony. "Distribution," "Dispersal," "Adaptation," "Variation," "Heredity," "Evolution," "Animal Industries," "Organization for Research," and the "Geological Succession in Animal Life," make up the 17 pages of this final chapter which must obviously be a wholly inadequate treatment of such general topics, unless they had been elaborated in specific cases throughout the work, which is not the case. One lays down the volume with the feeling that, save for the special part which deals with entomology, it is distinctly com-

monplace and that it cannot find any wide field of usefulness, despite the urgent need of the right kind of a text-book for the students of zoölogy in our agricultural colleges and in pre-medical courses. It is too much like a condensed edition of Parker and Haswell, with the merits of that admirable work left out, and its illustrations suggest this even more strongly; for out of a total of 269 illustrations for the entire book, 35 are indicated as taken from Parker and Haswell and 110 others are identical with illustrations appearing in Parker and Haswell, though quoted as from their original instead of their apparently more immediate source. They are moreover in many cases printed from badly worn plates which should have long ago gone to the scrap heap and for this feature the publishers deserve little credit. Several of the figures taken from photographs by the author, are of very little value, the one of a polyzoön (Fig. 78) showing nothing but blotches of black and white and looking more like the "mountains of the moon" than anything the writer can recall having seen figured.

Moreover, the writer would sharply take issue with the entire plan of the course here presented, for any students whether with economic interests or not. This is the old course in comparative anatomy from amoeba to man and one which may be said, with no belittling of the value in its proper place of vertebrate and invertebrate comparative anatomy, to be in no way representative of the kind of course in General or Introductory Zoölogy which is acceptable to most teachers of this subject to-day. From what the writer knows of the present feeling among zoölogists, such a course, like one in General Physics or General Chemistry, should aim at the general, foundational principles of the science, illustrating these by such animal forms as are best suited to the subject in hand. It should represent intensive rather than extensive study and should approach from the viewpoint of each form as an animal rather than as an echinoderm, a mollusc or a vertebrate. It should represent in an adequate way the essentials of general topics such as animal ecology and physiology and the problems which are naturally grouped about the theory of evolution. The trend of zoölogy to-day is toward the investigation of the fundamental activities common to all living things and this must find expression in our text-books for elementary

college courses by the presentation of the general conclusions which have already been reached and by the subordination of details to their proper illustration of such topics. That a course of this kind is not a difficult one for the student to properly grasp, the writer knows from his own experience, and he has had abundant reason to believe that it is exactly the kind of course which agricultural and pre-medical students need as a foundation for subsequent work in their anatomy, physiology and the like of man and the higher vertebrates. We have no text-book which expresses this point of view in such a way as to include the many important results obtained in the past decade and when such books come they will fill an urgent need, and if they are well done will go far toward adding to the dignity of zoölogy and toward setting its problems before our students as well worthy the best efforts of men.

W. C. Curtis.

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NOTE.

The Second International Anatomical Congress is to be held at Brussels during August, 1910. By a recent decision of the International Committee the exact date has been fixed, August sixth to tenth. It is hoped by the Committee that a large number of the members of the Association of American Anatomists will attend the Congress. Those who expect to join the Congress are requested to inform the undersigned, who is serving as the American member of the Committee. A circular giving full information will be issued later and communicated to all members of our Association.

CHARLES S. MINOT.

THE ANATOMICAL RECORD

Vol. III.

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No. 6.

I. CONCOMITANT ASSIMILATION OF THE ATLAS AND OCCIPUT WITH THE MANIFESTATION OF AN OCCIPITAL VERTEBRA.

II. NOTES ON A HYPOCHORDAL BRACE.

BY

THOMAS DWIGHT,

From the Department of Anatomy, Harvard Medical School.

I.

The simultaneous occurrence of fusion of the atlas and occiput, with the presence of a more or less distinct occipital vertebra, is of much importance in the discussion concerning the significance of numerical variations of the vertebral column. The observations by Zoja¹ and Swjetschnikow² both deal with the manifestation of an occipital vertebra that is most developed in its anterior and lateral portions. Although we find vague allusions in literature to the simultaneous occurrence of these two conditions, yet, so far as I know, these two anatomists are the only ones who have observed them. In point of fact it was the Russian who recognized the occipital ver-

¹Zoja, G. *Intorno all' atlante stude antropo-zootomici. Con una tavola. Letture fatte nell' adunanza 4 marzo, 1° aprile, 13 maggio, 17 giugno 1880 e 19 maggio 1881.* Pp. 269-296.

²Swjetschnikow. *Ueber die Assimilation des Atlas und die Manifestation des Occipitalwirbels beim Menschen.* Arch. für Anat. u. Physiol., Anat. Abth. 1906, pp. 155-193.

tebra in Zoja's specimen. The case to be described in this paper differs from them in that the posterior arch of the occipital vertebra has a free point. Similar appearances have been found on isolated skulls, but I believe this is the first time it has been seen when the atlas is fused. It makes the fact doubly sure to have the free points of the imperfect posterior arches of the atlas and occipital vertebra appear in series one above the other (Fig. 1). This body presented other vertebral irregularities: a supra-sternal bone and (perhaps) a hypochondral brace of the axis (Fig. 5). The last feature is considered in the second division of this communication.

These observations were made on the body of a white man, æt. 50, dissected at the Harvard Medical School, in the season of 1907-08. The skeleton was distinctly pathological, as is often the case with very exceptional vertebral variations. Thus, the two cases which I have reported of 26 præ-sacral vertebræ on one side and 25 on the other were both extremely pathological.³

The calvaria is a fine specimen of hyperostosis manifested on the inner table and especially in the frontal region, where it presents a hummocky surface with a maximum thickness of nearly 18 mm. Towards the posterior inferior parietal angle the thickness is about 12 mm. The buccal surface of the hard palate presents a similar condition (Fig. 4).

The vertebral formula is as follows, omitting any mention of the occipital vertebræ: C. 7, T. 13, L. 5, S. 5, C. 4. The atlas is fused with the occiput, one might say absorbed into it, so far as some parts are concerned. The axis and third vertebra are fused, the fusion dating undoubtedly from early embryonic life (Figs. 2 and 5). On the left the lateral portions of the two vertebræ occupy their normal relations. On the right they are very close together. The laminae, though fused on the left, retain their distinctness, and the spinous process ends in two knobs, one above the other, each representing the lateral termination of the bifurcated spines of the two vertebræ, while on the right there is but one knob for the

³Dwight, Thomas. Description of the Human Spines Showing Numerical Variation in the Warren Museum of the Harvard Medical School. *Memoirs of the Boston Soc. Nat. History*, V, 237-312. 1901.

two. The spines of the fourth, fifth and sixth cervical vertebræ are bifid. The laminæ of the sixth vertebra present on each side a sharp point (Fig. 2, L.) rather less than 1 cm. from the spinous process. That on the left is the larger. The fifth vertebra presents a very small similar projection on the left side only. The bodies of the sixth and seventh cervical and first thoracic vertebræ are fused through prominent exostoses. This is evidently the result of a pathological process, and is accompanied with distortion of this region, the details of which do not seem to the purpose. There are several projections on the ventral aspect of the bodies of the vertebræ in the thoracic region which would ultimately have led to fusion, if they have not already done so, and one on the second lumbar vertebra. Apart from this last feature, the lumbar vertebræ are normal, though the relative spread of their transverse processes is not that of a normal lumbar region. This is owing to the transitional character of the twentieth vertebra, which has been reckoned a thirteenth thoracic. The change in direction of the articular processes occurs below the twelfth thoracic. The costal elements of the twentieth vertebra are free, but insignificant. The right one measures 2.5 cm., the left one 3.3 cm. It is really a matter of taste whether we say that there are thirteen thoracic vertebræ and five lumbar, or twelve thoracic and six lumbar. The twelfth rib measures 13.5 cm. on the right and 14 cm. on the left. There are seven sternal ribs on both sides. On the left the cartilage of the eleventh joins that of the tenth—it probably did not do so on the right. The twenty-sixth vertebra (first sacral) is the *fulcralis*, i. e., the most important one in supporting the sacrum. The third sacral vertebra presents a sudden change in the curve (Hermann von Meyer's *conjugata vera*). The first coccygeal is fused with the sacrum. Thus, except in the last detail, the sacrum is perfectly normal, in spite of the increased number of vertebræ above it. The ensiform cartilage, ossified and fused with the body, is bifid below. The most remarkable feature of the sternum is a knob at the top of the posterior surface of the left half, at the median end of the clavicular notch. It is 6 mm. in height, tolerably clearly marked off, and suggests very strongly a *supra-sternal* bone fused with the manubrium. On the

right the sternum is prolonged upward perhaps a little more than usual, but presents no corresponding structure.

The Occipital Region. The anterior arch and lateral masses of the atlas are well developed, but it is so closely fused with the occiput that there is no sign of any occipital condyles. There is a small interval between the anterior arch and the occiput and on either side of this a deep groove above the atlas. The height through the region of the articular processes is about 2 cm. on the right and 1.5 cm. on the left. Seen from the intracranial side the fusion is very complete. The left posterior arch is, in the main, well developed, quite free, ending in a point some 5 mm. from the median line (Fig. 4). This piece, which is now separate, was in life connected by cartilage to the atlas just external to the inferior articular process. The left vertebral artery grooved its superior surface. The representative of the right posterior arch of the atlas is a thin sliver of bone, the point of which had been broken off (Figs. 1, 3, 4). It was less than 15 mm. in length when measured and probably never was more than 2 or 3 mm. longer. This was separated by a mere crack from the base of the skull at the border of the foramen magnum. The vertebral artery, smaller than the left one, judging from the size of the foramen in the axis, must have passed below this rudimentary arch. The lateral parts of the atlas differ very much on the two sides (Fig. 3). On the left, the costal element of the atlas is wanting, so that the transverse foramen is completely open in front, except for a very slight hook projecting from the median side. The transverse process is strong, and ends in a knob which rests against the vaginal process of the temporal. On the right the lateral mass is inextricably mixed with the occiput. The transverse process is short and indistinct till near its end, which projects strongly backward; but a projection from near the end runs somewhat forward and is assimilated into an ill-marked paramastoid process. The groove already mentioned, anterior to the foramen magnum at the junction of atlas and occiput, has on the right a deeper part, which extends from the anterior condyloid foramen laterally to the entrance to a canal between the transverse process and the skull, which runs antero-posteriorly. (It is unlikely that there was an sub-occipital nerve on the right.)

There is an unquestionable manifestation of the posterior arch of an occipital vertebra on the right; and a less distinct one on the left. The right arch forms the boundary of the foramen magnum, but some 3 or 4 mm. before reaching the median line it ends in a point, which is separated from the bone above it by a sharp cleft some 3 mm. deep. This is seen most strikingly on the inner aspect (Fig. 1), but is clear also on the outside (Figs. 3 and 4).

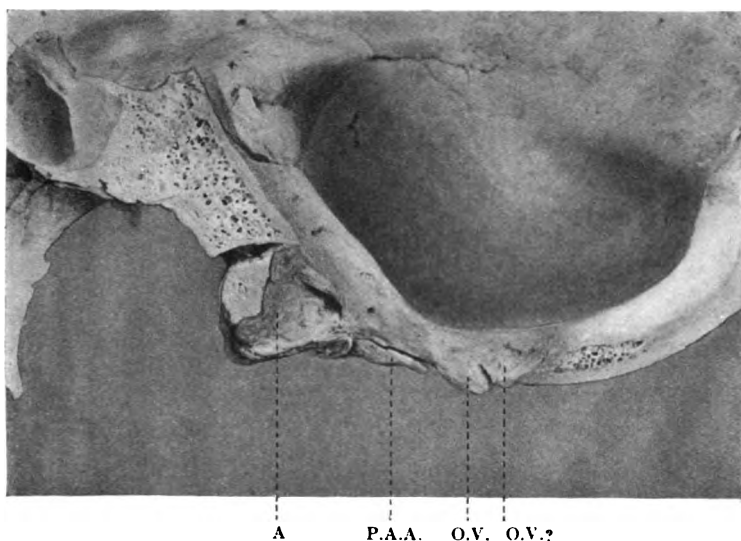


FIG. 1.

A., Atlas. O.V., Manifestation of occipital vertebra. P.A.A., Posterior arch of atlas.

On the right, close to the middle line, and nearer to it than the end of the occipital vertebra above described, there is a small knob which might be held to indicate the termination of another occipital vertebra above it (O. V. (?)). On the lower surface of the left posterior border of the foramen magnum there is a very fair manifestation of the arch of an occipital vertebra, marked off by a groove. It ends rather vaguely some 2 or 3 mm. from the median line (Figs. 3 and 4, O. V.).

The right anterior condyloid foramen is small. On the left it is subdivided into a larger lower and a smaller upper division by a tongue of bone projecting forward from behind and reaching the anterior border. This foramen opens into a groove, already alluded to, between the front of the atlas and the occiput. From the region of the condyle for some distance forward the borders of the occipital bone grow downward so as to shut out the atlas from forming a part of the wall of the spinal canal, and placing it in the main in front of the occiput instead of below it. This is particularly marked on the left. Fig. 3 shows a deep vertical cleft between these bones on the interior surface.

Certain peculiarities are to be noted in the region of the odontoid, which is very long, measuring 19 mm. on the posterior surface, from the lower border of the facet for the transverse ligament to the top. The superior part of the odontoid (nearly one-half) is in the same vertical plane as the anterior surface, but does not reach back to the posterior one. Seen from behind this upper part is a roughened irregular piece of bone, giving a suggestion of an additional element (Fig. 2). A noteworthy point is the difference of position of the anterior and the posterior articular facets of the odontoid. In fact, the highest part of the posterior one does not extend above the level of the middle of the anterior one, which latter reaches to the very top of the odontoid. This is shown in Figs. 2 and 5. The superior articular facets of the axis slant perhaps a little more steeply than usual downward and outward, and the pedicles of the axis decline very steeply behind them. All this would imply that the head must have been carried with the chin high. When we consider the fusion, in some cases congenital and in others pathological, of so many of the cervical vertebræ, it would seem that the power of nodding must have been nearly abolished. Presumably the joints above the axis allowed a great deal of irregular motion.

Besides these manifestations of an occipital vertebra in the region of the foramen magnum, there is on the left side an apparent manifestation of one seen from the front, made by modifications of the anterior border of the occipital bone, which is developed into a horizontal shelf where it bounds the jugular foramen, and, continued

forward, forms the line marking off the groove above the anterior arch of the atlas. This manifestation is much less clear on the right.

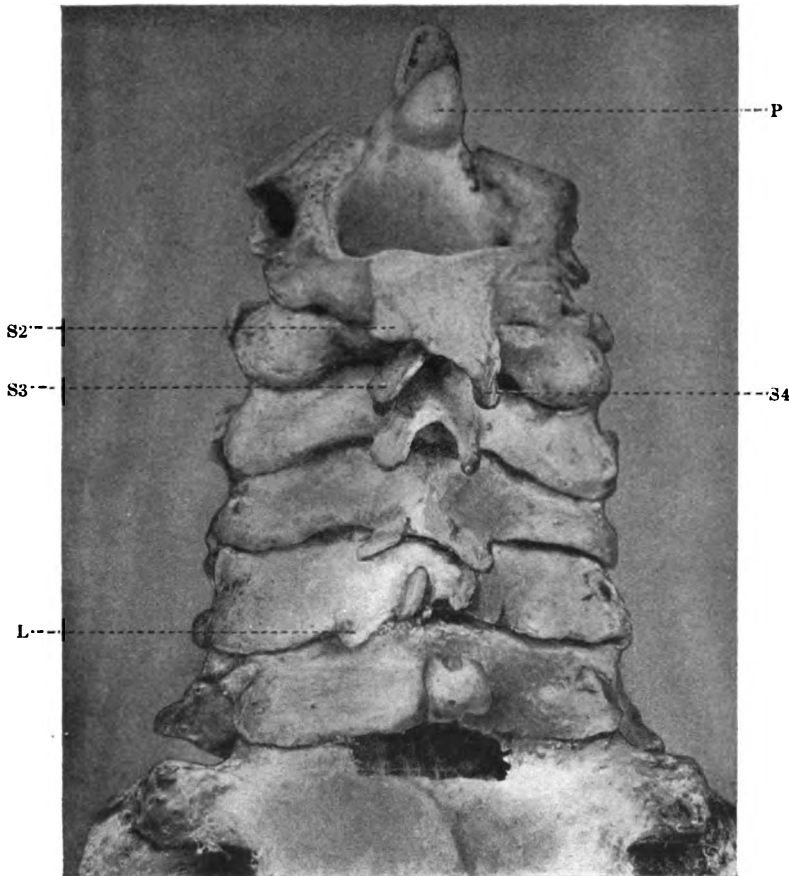


FIG. 2.

L., Point on left lamina of 6th vertebra.

P., Posterior articular facet. S2, Left lateral knob of spine of 2d vertebra. S3, Left lateral knob of spine of 3d vertebra. S4, Right knob resulting from the fusion of the right lateral knobs of the 2d and 3d vertebrae.

On the latter side a delicate process from the border of the occipital divides the exit of the venous canal from the nervous one (Fig. 3, J. F.).

This spine presents also a possible hypochordal brace which is considered in the second part of this paper.

The following facts are to be noted in this case. The presacral vertebræ are increased by a transitional one between the thorax and

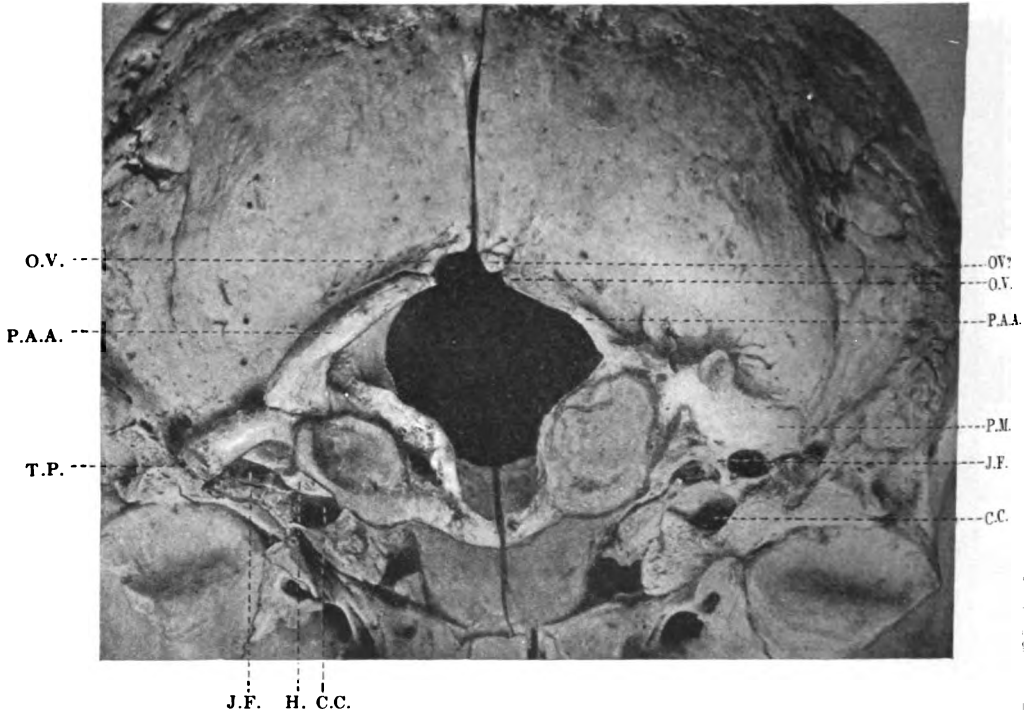


FIG. 3.

C.C., Carotid canal. J.F., Jugular foramen.—under the leader is the spicule dividing it. O.V., Manifestation of occipital vertebra. P.A.A., Posterior arch of atlas. P.M., Paramastoid processes. H., Hook by transverse foramen of atlas. T.P., Left transverse process of atlas resting on vaginal process of temporal.

loins, bearing short movable costal elements. The ribs on the vertebra above it are longer than is usual for last ribs. The second and third vertebræ are fused, the fusion of the arches being more intimate on the right. The atlas is fused much more intimately with the occiput on the right, and the right arch is much less devel-

oped; yet the manifestation of the occipital vertebra, as shown by its free point, is more advanced on the same side. On the right, also, there is the hint of the presence of the point of the arch of still another occipital vertebra. The suggestion of the antero-lateral part of an occipital vertebra is more distinct on the left.

It is much to be regretted that in so few cases of variations about the foramen magnum do we have an account of the entire column. Smith⁴ remarks that "true assimilation of the atlas is rarely, if ever, an isolated anomaly of the cranio-vertebral axis." There can be no doubt as to the correctness of this statement. In support of it Smith points out that the cases of Morgagni, Schiffner and Lambl had also fusion of the axis and the third vertebra; that in two other cases there were cervical ribs; and that a case of his had beside fusion of the axis and third vertebra, a cervical rib and other striking anomalies. To these I would add that among the spines in the Warren Museum showing numerical variation, there are three complete ones with fusion of the atlas and occiput, of which one must be discarded because the fusion is to be considered pathological, and one specimen in which eight vertebrae are preserved. The first (spine 561) has an extra vertebra at the junction of the back and loins, with small free costal elements, while the ribs of the twelfth thoracic are very long. The twenty-fifth vertebra is more or less sacralized on both sides. The next (spine 24) is very normal, only the arch of the last lumbar is distinct and there are certain distinct epiphyses (?) on the caudal side of some of the lumbar articular processes. I have excluded spine D-7 for the reason given. It has only four lumbar vertebrae. The specimen which consists of the neck and the top of the thorax has suffered the loss of the left transverse process of the atlas, probably by accident. On the right the costal element is wanting. Presumably it was free and was lost. Just the same may be said of the right costal element of the seventh. The label states that the vertebral formula is believed to have been normal. It may be repeated that the spine which is described in this paper has an

⁴Smith, G. Elliot. The Significance of Fusion of the Atlas to the Occipital Bone, and Manifestation of Occipital Vertebrae. *British Med. Journ.*, 1908, 594-596.

extra vertebra at the junction of back and loins and fusion of the axis and third, which last feature seems remarkably common in these cases.

We have known for centuries that the atlas may be assimilated more or less completely with the occiput, and for a few years we have accepted the manifestation of an occipital vertebra, usually an inseparable part of the occipital bone. The most perfect observation is that recorded by v. Schumacher,⁵ who described several pieces of a fairly developed vertebra between the atlas and occiput, without bony connection with either. Recently we have had discussions as to whether certain "manifestations" on the bases of isolated skulls were to be considered as belonging to one region or to the other. Even without the light that is thrown on such peculiarities when the spine is present, we must recognize that the case is the same as at other transitional parts of the spinal column. A twenty-fifth vertebra may be a sacral vertebra or a lumbar vertebra, or a cross between the two. It may even be both at once in its two halves. Similar observations may be made at the two ends of the thorax. It is idle to discuss which vertebra a particular vertebra *is*. All we can say is which one it is like. I agree fully with Bateson that we must not treat the members of such a series as individuals. The details of their structure vary according to circumstances. Many years ago Topinard discussed at length which vertebra was wanting in a spine in which there were only eleven thoracic ones. We now know better; but it would seem that in discussing the occipital region we are slow to apply the principles we follow elsewhere.

The great importance of the present specimen is that it is one of the few undoubted cases of assimilation of the atlas and occiput, with manifestation of an occipital vertebra. Perhaps it is the only one. What is most remarkable is that both these processes have made the greatest progress on the same side. The cases of Zoja and Swjetschnikow each show connection between the skull and the spine by means of paramastoid processes from the skull and

⁵Schumacher, Siegmund v. Ein Beitrag zur Frage der Manifestation des Occipitalwirbels. *Anat. Anz.*, XXXI, 1907, 145-159.

anomalous upgrowths to meet them from the transverse processes of the atlas. In the latter's case there is a very slight ossification between the bones at one condyle, which probably is pathological. Now in both these cases the posterior arch of the atlas is apparently both free and well developed. Hence they appear to me to belong to a different class from those in which the body and posterior

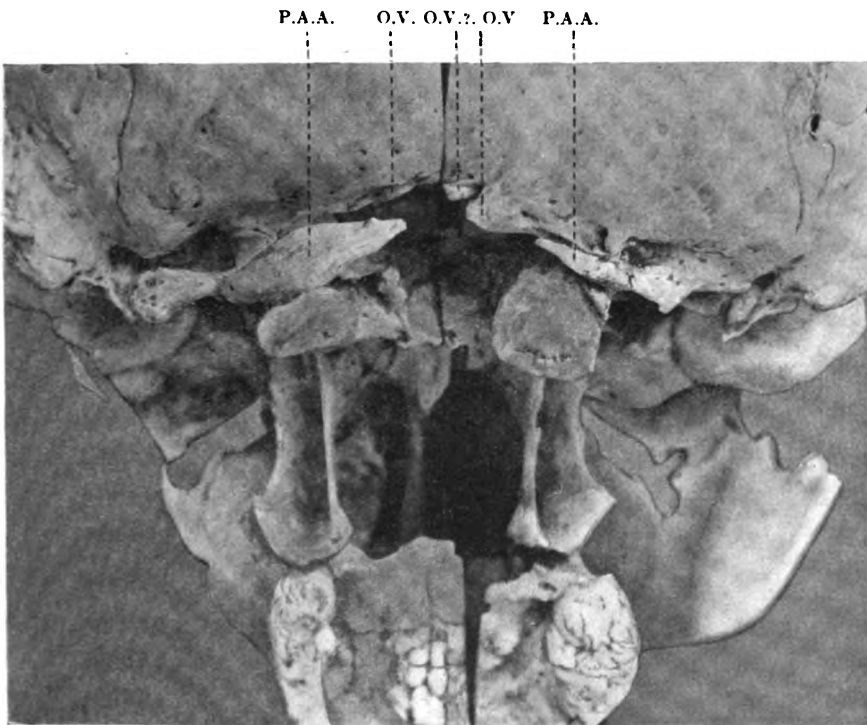


FIG. 4.

P.A.A., Posterior arch of atlas. O.V., Manifestation of occipital vertebra.

arch of the atlas are more or less assimilated with the skull. I regret that Swjetschnikow does not give a figure of his specimen, but he tells us that it is "*demjenigen von Zoja äusserst ähnlich.*" Although the use of color by the Russian anatomist on Zoja's figure is hardly justifiable, as appealing too much to the imagination, it is not to be denied that the tubercle on the anterior border of the

foramen magnum points distinctly to the manifestation of an occipital vertebra of which other parts are indicated. The occipital vertebra must be admitted in these cases; but there is no real assimilation of the atlas and occiput.

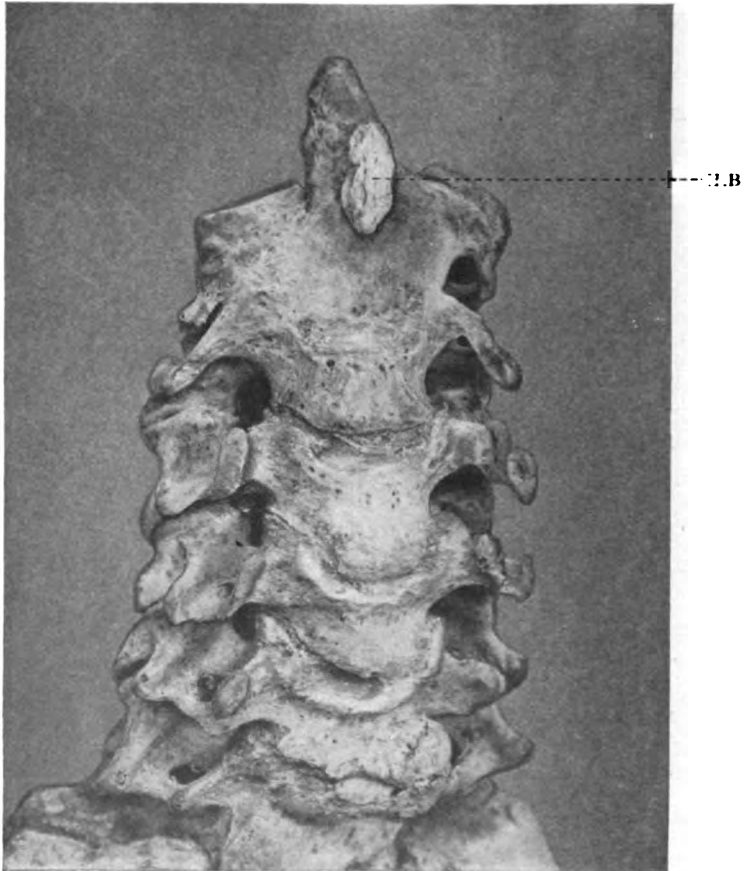


FIG. 5.

H.B. Hypochordal brace.

The present specimen shows far more conclusively the presence in the same body and most markedly on the same side) of two distinctly antagonistic processes, according to the popular theory which would have the one a return to the past and the other a step toward

the future. It is therefore one more piece of evidence for the conservative theory of variation around a mean.

II.

It remains to speak of the *hypochordal brace* (Fig. 5), if indeed that be its morphological significance. It is a stout ossification close on 15 mm. long, with the greatest breadth of some 7 mm. situated free on the front of the axis, its upper part somewhat overlapping the lower border of the anterior articular surface of the odontoid. The anterior arch of the atlas presents a kind of a facet looking downward and forward, which presumably locked with its upper part.

As to the significance of this element, it may be said in favor of its being nothing but an accidental ossification that the body was a distinctly pathological one, showing in many places a tendency to the proliferation of bone. This, in fact, is not to be denied. Nevertheless, the anterior surface of this ossicle has what one may call a "finished" appearance. Whether the fact of its upper dorsal surface being so shaped as to enable it to "lock" with the anterior arch of the atlas is of importance, is a question more easily asked than answered. The fact, however, that an ossification is occasionally found at this precise point speaks strongly for its having a morphological significance. Yet if it be an hypochordal brace, it can be only that of the axis, and embryology leaves one in doubt whether this explanation is legitimate. There is indeed such a cartilaginous *anlage*, but according to Bardeen it is very transient. This spine is so abnormal, showing so many irregularities that must have occurred at a very early period, that it seems favorable soil for such an unexpected growth; but I have recently seen another instance of this ossification, though a smaller one, in a spine which, if not quite normal, was not remarkable.

Just before revising the proof of this paper I received the *Anatomischer Anzeiger* of May 5, 1909, containing Smith's case of fusion of atlas and occiput with the manifestation of an occipital vertebra.

II. ON THE ORIGIN OF THE PULMONARY ARTERIES IN MAMMALS.

BY

JOHN LEWIS BREMER.

Harvard Medical School.

In 1902 I published a paper on this subject,¹ a resumé of which is here given. The pulmonary arteries in man, rabbit, cat, and dog, appear as symmetrical vessels, one rising from each fifth, or pulmonary arch. With the growth of the truncus pulmonalis, and its torsion about the bulbus aortæ, the two pulmonary arches are wound, as it were, around the bulbus, and their walls thus brought into contact are absorbed, so that the truncus pulmonalis grows longer at their expense, the point of bifurcation moving continually farther from the heart. The left arch, being the outside one in this rolling process, receives the most pull, becomes the straighter and therefore the larger vessel, and is shortened more rapidly. As a result, the point of bifurcation of the truncus pulmonalis reaches the left pulmonary artery while the right pulmonary artery is still seen arising from the right arch some distance dorsal to this point. (See diagram, page 338). The portion of the right pulmonary arch between the origin of the pulmonary artery and the dorsal aorta becomes obliterated, the anterior portion of the arch remains continuous with the artery, and we then have the condition described by Rathke,—the two pulmonary arteries apparently arising together from the left pulmonary arch. It should be noted, however, that the right pulmonary artery of the fetus includes, beside the homologue of the left pulmonary artery, the proximal portion of the right pulmonary arch.

In the pig, although the pulmonary arteries first appear, as usual, as symmetrical offshoots, one from each pulmonary arch; and although the fetal condition is practically the same, the intermediate steps

¹Am. Jour. Anat., Vol. I, No. 2, p. 137, 1902.

are different. The two arteries, while their points of origin are still far apart, bend toward each other lower down, and soon anastomose to form a long vessel, connected at its upper end with both the right and the left pulmonary arches, and forking at its lower end to send a branch to either lung. Soon the upper, or proximal, part of the right pulmonary artery becomes obliterated, leaving the common stem in communication with the left arch only, thus forcing the blood to both lungs to pass through the left pulmonary arch.

Since 1902 I have been able, through new acquisitions to the Harvard Embryological Collection, to trace the development of the pulmonary arteries in other mammals,—opossum, sheep, and guinea-

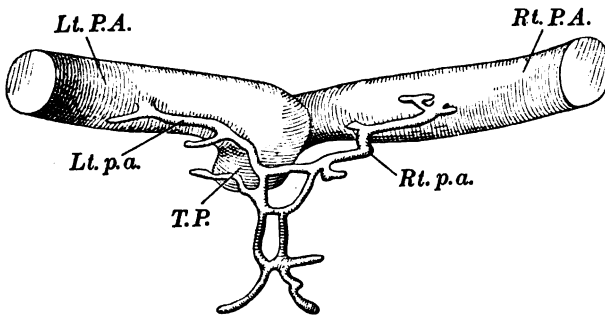


FIG. 1.—Guinea-pig, 7.7 mm. (H. E. C., Series 1512, sections 190-233.) Dorsal view. *P. A.*, pulmonary arches, left and right; *p. a.*, pulmonary artery; *T. P.*, truncus pulmonalis. $\times 125$ diam.

pig, and to make a few observations on the cow and deer. In the opossum and sheep the picture is essentially the same as in man, rabbit, cat, and dog, though in the sheep the two pulmonary arteries are brought to the bifurcation at almost the same time, so that very little of the right arch plays a permanent rôle in the right pulmonary artery. In the guinea-pig, on the other hand, the development of these arteries follows very closely that described in the pig, but with one important difference. In both animals the arteries originate as symmetrically placed vessels from the right and left pulmonary arches, in both they bend toward each other and anastomose, and in both the upper end of one pulmonary artery, from the arch to the anas-

tomosis, becomes obliterated, leaving the anastomosis and the lower ends of both arteries connected with only one arch. In the pig the left arch remains in communication with the combined pulmonary arteries, in the guinea-pig the right; in the pig the entire right pulmonary arch from the bifurcation of the truncus pulmonalis becomes

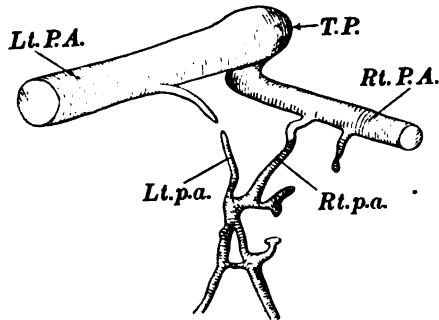


FIG. 2.—Guinea-pig, 8.0 mm. (H. E. C. series 1513, sections 277-315.)
× 125 diam.

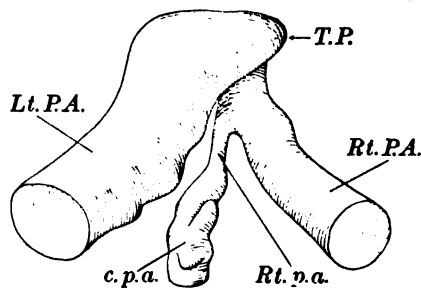


FIG. 3.—Guinea-pig, 8.2 mm. (H. E. C. series 770, sections 230-256.)
c. p. a., conjoined pulmonary arteries. The lower portion of the pulmonary arteries not shown. × 125 diam.

obliterated, in the guinea-pig the anterior part of the arch, as far as the origin of the right pulmonary artery, becomes incorporated in the adult pulmonary artery, and only the posterior part is lost.

Minor differences of development occur in the two animals, as may be seen by comparing the accompanying drawings with the figures of pig embryos in the former paper. The pulmonary arteries in the guinea-pig are seen to form a meshwork of capillaries and to preserve

their irregular course even after the upper part of the left artery has become obliterated. From the beautiful injection of the blood vessels of embryos made by Dr. H. M. Evans of the Johns Hopkins Medical School, it is probable that in all embryos the pulmonary arteries, in common with all other small arteries, arise at first by a capillary network, and that only later the main channels become larger and free from the surrounding capillaries. Remnants of this capillary origin of the pulmonary arteries are not infrequently seen in embryos, as for instance the short vessel from the right arch in Figure 2, loop formations near the pulmonary arch, side twigs from the arteries, even (in one instance in a sheep embryo of 10.0 mm., H. E. C. series 1340, sections 398-409) an artery which is double throughout most of its course, making a very long loop. In the guinea-pig this early condition lasts longer than in the pig or the other mammals studied,—the pulmonary arteries are later in straightening out and becoming distinct channels.

Another minor difference lies in the fact that, although in both pig and guinea-pig the two pulmonary arches are wound about the bulbus aortae as described above, in the guinea-pig there seems to be no fusion (or at least a much delayed fusion) between the two, so that the truncus pulmonalis is not lengthened, as in other mammals, at the expense of the two arches; the two arches merely lie one below the other, side by side. This is shown in Figure 3, in which the left arch is seen to overlap the right for a considerable distance; if fusion had taken place, as in the pig, the pulmonary artery would already seem to spring from the bifurcation instead of distinctly from the right arch as in the drawing.

In 1904, two years after my first article, Sakurai published a paper in which he describes the growth of the pulmonary arteries in the deer.² The original starting point is the same, two symmetrical buds, one from each pulmonary arch; but the left pulmonary artery, according to this author, moves toward the bifurcation of the truncus pulmonalis, and then continues farther to the right until it arises distinctly from the right arch, near to the origin of the right artery.

²Anat. Anzeiger, Band XXV, No. 14, p. 321, 1904.

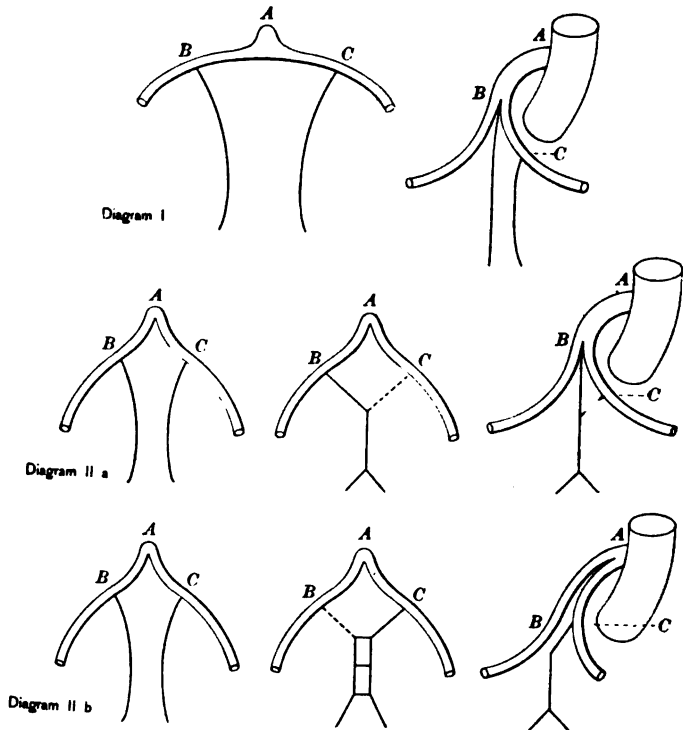


DIAGRAM I.—Shows the original symmetry of the pulmonary arteries, and, in the second figure, the result of the torsion about the bulbus aortæ. *A*, truncus pulmonalis, at the point of the original bifurcation; *B*, point on left pulmonary arch where the left pulmonary artery rises; *C*, same for right side.

DIAGRAM II.—(a) In the pig; shows the original symmetry, the pulmonary arches less wide spreading, the arteries nearer together. In the second figure, the anastomosis of the arteries, and in the third figure, the result of torsion. (b) Same for the guinea-pig.

I feel obliged to doubt, not the figures in Sakurai's paper, but the interpretation of them. Certainly in the deer³ in this laboratory I find nothing that would lead one to suspect that the deer differed from man, rabbit, sheep, cat, or dog in the development of its pulmonary arteries. In embryos up to 9.8 mm. in length the picture is the usual one, the two pulmonary arteries approaching each other as the bifurcation of the truncus pulmonalis is brought farther dorsal; and in an embryo of 18.6 mm. (H. E. C., series 1230), whose general characteristics show it to be younger than the oldest figured by Sakurai, the left pulmonary artery is seen arising from a short stem common to it and the right pulmonary artery. The posterior part of the right pulmonary arch no longer exists. The arteries are well established, with thick walls, so that any migration would seem impossible. A short common stem for the two pulmonary arteries in the fetus is not uncommon, and I should prefer to interpret Sakurai's last figure as an unusual lengthening of this common stem rather than as a migration of the left artery along the right arch, especially as the landmark, the posterior part of the right pulmonary arch, is lacking.

If we accept this interpretation of Sakurai's figures, the different methods of the development of the pulmonary arteries so far reported fall into two main groups, one of which may be subdivided. (1) In man, cat, dog, rabbit, sheep, cow, deer (?), and opossum the development may be described by Diagram I. (2) In the pig and guinea-pig the development differs from that of the other mammals mentioned, and may be shown roughly in Diagram II, (a) representing the pig, (b) the guinea-pig.

In this curious grouping of the animals studied, generic lines seem to have no influence. In my former paper it was suggested that the large size of the auricles in the pig embryo caused the crowding together of the pulmonary arteries and their consequent anastomosis, and I again offer this explanation. In the guinea-pig also the auricles are very large at the time when the pulmonary arteries

³*Cervus capreolus*. The laboratory is indebted to Professor Franz Keibel for the embryos.

are growing, but there seems to be no crowding of the tissue surrounding the trachea from the sides. The mechanism seems to be slightly more complicated. The large auricles and large sinus venosus separate the trachea posteriorly from the bulbus aortae and the truncus pulmonalis anteriorly more, it seems to me, than is usual in animals without the large auricles. The aortic arches are straightened out more, the figure they present with the bulbus or truncus becomes more like a Y than like a tuning fork, and hence the pulmonary arteries, starting out at right angles to the pulmonary arches, point toward each other instead of backward, as in other animals. This purely mechanical result of large auricles seems to me to account for the difference of development between the pig and the guinea-pig and all other mammals studied. The cause of the larger auricles I do not know; nor can I explain why, after the anastomosis, the left artery in one case, and the right in the other, should remain permanently.

THE FIRST LYMPH GLANDS IN RABBIT AND HUMAN EMBRYOS.

BY

FREDERIC T. LEWIS.

Assistant Professor of Embryology at the Harvard Medical School.

In 1896 Saxer stated that the lymph glands in sheep and cow embryos arise from a plexus of lymphatic vessels.¹ "The connective-tissue between the lymphatic vessels of the plexus has at first a trabecular arrangement, but later one or more compact masses or islands are formed within it. From the beginning, the connective tissue which makes the trabeculae, or masses, is narrower meshed than that which surrounds it, and contains many blood vessels." However, he adds: "There can be no doubt that there are many plexus formations in embryonic tissue, having exactly the appearance of those from which lymph glands arise, which simply degenerate."

Kling, in 1904, emphasized the importance of the plexus stage and modelled the lymphoid trabeculae.² Although they connect with one another so as to form a continuous mass, his model has "an extremely irregular appearance." It shows that these structures have little resemblance to the future glands. Kling stated that from such a general mass portions were separated by constriction to form the basis for individual glands. But "lymph glands which have an isolated position appear from the first as solitary formations; each one arises independently."

A year later Miss Sabin wrote:³ "All of the nodes of the early

¹Saxer, F., Ueber die Entwicklung und den Bau der normalen Lymphdrüsen. Anat. Hefte, 1896, vol. 6, pp. 349-532.

²Kling, C. A., Studien über die Entwicklung der Lymphdrüsen beim Menschen. Arch. f. mikr. Anat., 1904, vol. 63, pp. 575-610.

³Sabin, F. R., The development of the lymphatic nodes in the pig and their relation to the lymph hearts. Amer. Journ. of Anat., 1905, vol. 4, pp. 355-389.

embryos, the primary nodes in the sense of Gulland, pass through this (plexus) stage. Lymphatic nodes which develop later in the life of the embryo, after lymphocytes occur, hurry through the primary process and show a considerable modification of it." Recently⁴ Dr. Sabin published the figure of a section through the jugular lymph sac in a human embryo of 30 mm., "to show the simple bridging of the sac which is the anlage of the first lymph node." In the pig she found that "the first node to appear develops from the lymph heart, which is in the supra-clavicular triangle behind the sternocleidomastoid muscle."

Thus, Saxer, Kling and Miss Sabin agree that the first lymph glands arise from trabeculae in a plexus of lymphatic vessels.

The plexus of lymphatics in relation with the internal jugular vein is a conspicuous feature in human embryos measuring from 30 to 40 mm. It is shown in Figs. 1 and 2 from an embryo of 42 mm. A portion of the vein is seen in the lower right corner of each photograph. In places the connective tissue trabeculae are broad and pale, as shown in Fig. 1. Elsewhere they are more slender and deeply staining, as in the left part of Fig. 1 and in Fig. 2. The latter is a section through the structure which Miss Sabin has described as the primary lymph gland.

The cells in the similar trabeculae of a 31 mm. human embryo are described by Kling as having "chiefly, if not exclusively, the char-

⁴Sabin, F. R., The lymphatic system in human embryos, with a consideration of the morphology of the system as a whole. *Amer. Journ. of Anat.*, 1909, vol. 9, pp. 43-91.

EXPLANATION OF FIGS. 1-6.

FIGS. 1 and 2.—Plexus of lymphatic vessels in relation with the internal jugular vein. From a human embryo of 42 mm. $\times 45$ diams. (Harvard Embryological Collection, Series 841, Section 432, and Series 838, Section 153, respectively).

FIGS. 3, 4, and 5.—Lymph glands from a human embryo of 42 mm. $\times 60$ diams. Fig. 3 shows the submental ("submaxillary") gland (Series 841, Section 589); Fig. 4 shows the external jugular gland (Series 841, Section 524); and Fig. 5, the circumflex scapular gland (Series 838, Section 321).

FIG. 6.—Subscapular lymph gland from a rabbit of 20 days, 29 mm. $\times 60$ diams. (H. E. C., Series 170, Section 1080.)

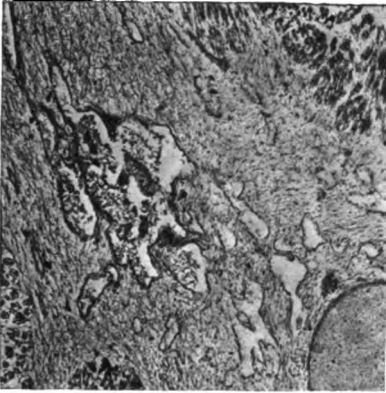


FIG. 1.

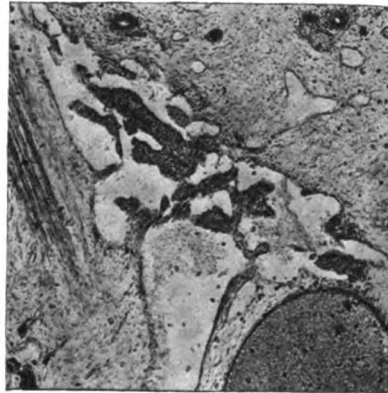


FIG. 2.

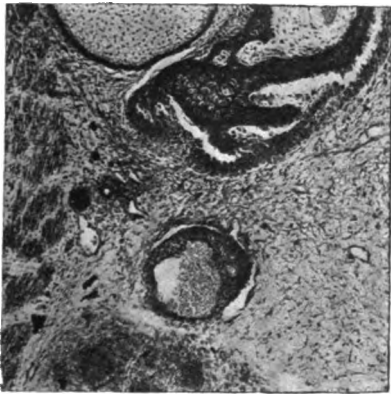


FIG. 3.

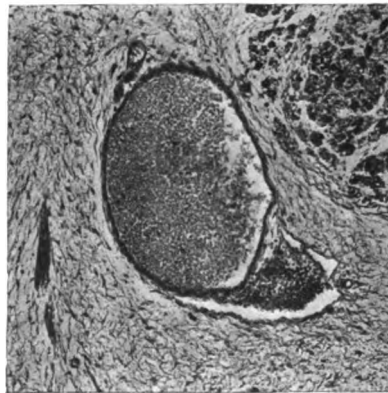


FIG. 4.

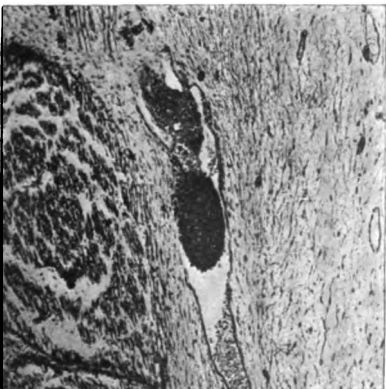


FIG. 5.

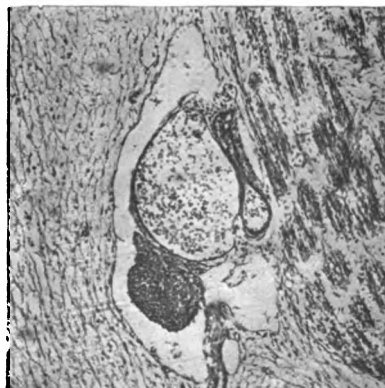


FIG. 6.

acter of fixed connective tissue cells." At 70 mm. "we find among pale oval nuclei, others of rounder form and darker stain which already suggest adenoid tissue." Similarly, in pigs of 80 mm. Miss Sabin found large, faintly staining, oval nuclei belonging to connective tissue, and small, round, deeply staining nuclei with coarser chromatin granules and a more distinct membrane, which belong to lymphocytes. "Between the connective tissue cell, especially the young forms, and the lymphocyte one can see every possible transition" (1905, p. 371). Saxer likewise found that "the lymphocytes, which later form the bulk of the lymph glands, arise *in loco*."

The examination of the bridges in the 42 mm. embryo shows the pale oval cells and the darker round ones apparently derived from them, and indicates that these trabeculae contain lymphoid tissue. They do not, however, constitute a lymph gland, but represent the material from which the chain of deep cervical lymph glands is to be derived. A sufficiently detailed study of the later stages of the plexus has not yet been made. Bonnot⁵ believes that it produces the "interscapular gland" of Hatai, which seems to be a collective term for the cervical fat and lymph glands.

Almost simultaneously with the lymphoid transformation of trabeculae among the jugular lymphatics, distinct lymph glands appear in the superficial tissues. These do not pass through a plexus stage, but from the first they resemble the glands of the adult. The striking difference in the arrangement of the deep and the superficial lymphoid tissue seems due to the fact that the deep tissue is molded about an involved pre-existing plexus; but the superficial glands develop freely in the loose subcutaneous tissue. The plexus stage may therefore be regarded as a complication in the development of the glands, rather than a fundamental condition which is sometimes hurried through, modified, or omitted.

In the human embryo of 42 mm. two superficial glands were found on either side of the head. Their position is indicated in Fig. 7. The smaller gland is in intimate relation with the submental branch of the anterior facial vein. A section through it is shown in Fig. 3.

⁵Bonnot, E., The interscapular gland. Journ. of Anat. and Phys., 1908, vol. 43, pp. 43-58.

At the upper border of the photograph a part of Meckel's cartilage is seen on the left, and the bone of the lower jaw on the right; the lower border of the photograph passes through the submaxillary gland. Between the submaxillary gland and the mandible the submental vein appears, surrounded by dense tissue. This dense lymphoid tissue is chiefly on the upper side of the vein, and it is bounded by a lymphatic

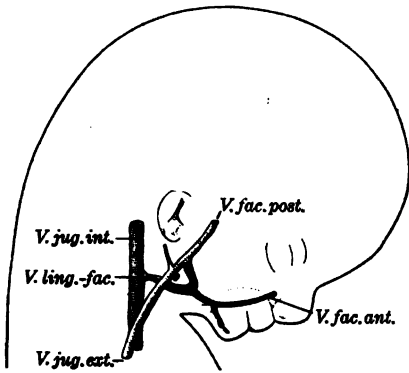


FIG. 7.

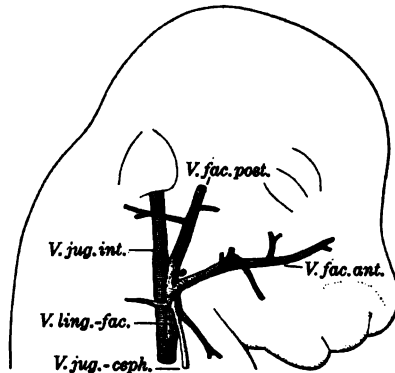


FIG. 8.

FIG. 7.—The head of a human embryo of 42 mm., to show the position of the submental ("submaxillary") and external jugular glands. $\times 2\frac{2}{5}$ diams. (H. E. C., 841.)

FIG. 8.—The head of a rabbit embryo of 29 mm. to show the position of the posterior facial gland. $\times 4$ diams. (H. E. C., 170.)

The veins shown are the anterior and posterior facial, the linguo-facial, the external and internal jugular, and the jugulo-cephalic. (The external jugular of man corresponds with the jugulo-cephalic of the rabbit and not with the linguo-facial; the latter in the rabbit is, however, usually called the external jugular. Cf. Lewis, Amer. Journ. of Anat., vol. 9, p. 33.)

vessel, crescentic in section. The submental vein sends branches into and through the lymph gland.

The other lymph gland in the head is in relation with the external jugular vein. It is shown in section in Fig. 4. Lymphoid tissue, enclosing small blood vessels, forms a rounded mass attached to the lower part of the vein. Its free surface is in relation with a crescentic lymph sinus. No other lymph glands were found in the head of this embryo.

In a human embryo of 30 mm. the submental⁶ and external jugular glands were not found. They are not mentioned in four embryos of 46-50 mm. described by Miss Sabin, but she has recorded that in an

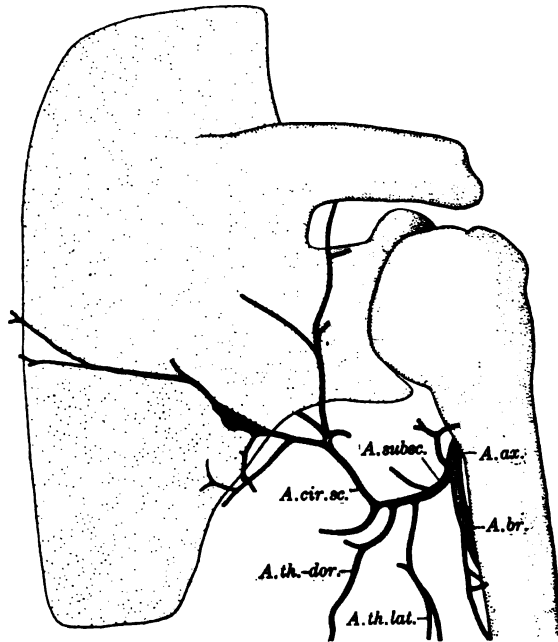


FIG. 9.—Reconstruction of the arteries in the axilla of the human embryo of 42 mm., to show the position of the first axillary lymph gland. $\times 10$ diams. (H. E. C., 838). The subscapular branch of the axillary artery is seen to divide into the circumflex scapular and thoraco-dorsal arteries. The lymph gland is along the latter. The brachial and lateral thoracic arteries are also shown:

80 mm. embryo "there are secondary lymph nodes along the veins of the neck; for example, along the external jugular vein next the parotid gland and along the facial vein at the angle of the jaw."

"It seems desirable to name the early lymph glands for the veins which they accompany and this has been done. It is to be noted, however, that in the adult there are several glands along the submental vessels, the anterior ones forming the submental group, and the posterior ones the submaxillary group. The submental gland of the 42 mm. embryo belongs evidently with the submaxillary group of the adult.

Since the early lymph glands develop with such regularity in the rabbit, it seems quite possible that these glands noted in human embryos of 80 mm. are the ones appearing at 42 mm.

The Harvard collection includes three rabbits of 29 mm. (20 days) cut in the transverse, sagittal and frontal planes respectively.

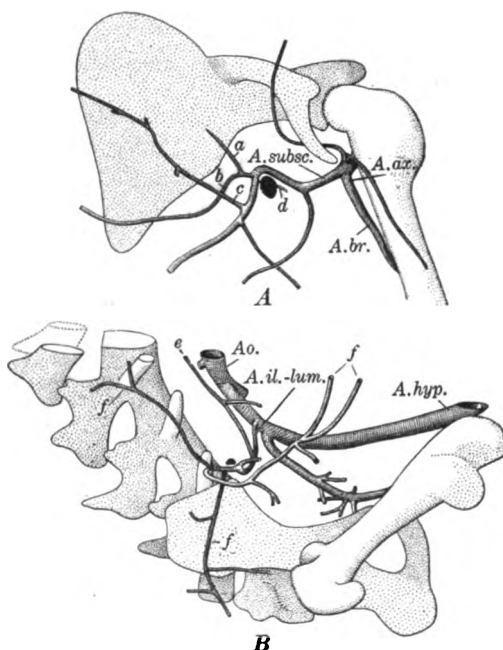


FIG. 10.—*A*, reconstruction of the arteries in the axilla of the 29 mm. rabbit, to show the position of the first axillary lymph gland. $\times 10$ diams. (H. E. C., Series 170). *B*, reconstruction of the arteries in the pelvis of the same embryo, to show the first pelvic gland. $\times 10$ diams.

The arteries labelled are the axillary, brachial, subscapular, aorta, ilio-lumbar and hypogastric.

These embryos all show a lymph gland near the junction of the anterior and posterior facial veins (Fig. 8). Except at this point, no lymph glands were found in the head.

The most distinct lymph gland in the body, in these rabbits and in the human embryo of 42 mm., is in the axillary region. In the human embryo it is an accumulation of lymphoid tissue surrounding

the circumflex scapular artery and vein, and forming a lenticular mass bulging into the accompanying lymphatic vessel. Its position is shown in Fig. 9, and a section through it is photographed in Fig. 5. It lies next the muscle in the deep subcutaneous tissue. This gland was not found in a 30 mm. embryo, although at that stage the circumflex scapular vessels are accompanied by lymphatics. It is not specifically mentioned by Miss Sabin, and if it occurred in the embryos studied by Kling it was overlooked. At 70 mm. he found all of the axillary groups represented *except* the subscapular group (p. 588).

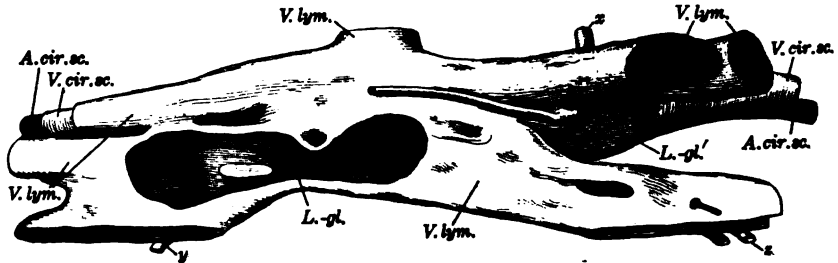


FIG. 11.—Wax reconstruction of the human axillary gland shown in Figs. 5 and 9. $\times 40$ diams. A. cir. sc. V. cir. sc., circumflex scapular artery and vein; x. y. z., small blood vessels, of which x is so surrounded by lymphatic vessels, V. lym., that it seems to perforate them; L.-gl., L.-gl', nodules of lymphoid tissue.

A corresponding gland occurs in rabbit embryos. It can be identified in a specimen measuring 25 mm. (18 days), and it is well defined in all three of the 29 mm. embryos. It is in relation with the subscapular vessels, which are relatively large in the rabbit (Fig. 104). A section through the gland is shown in Fig. 6.

Since the axillary glands seem to be the largest and most clearly defined, they were reconstructed in wax. The gland in the human embryo is shown in Fig. 11. Along the top of the model the circumflex scapular artery and vein pursue a parallel course, accompanied by the lymphatic vessels, V. lym. As the blood vessels approach the gland the mesenchyma around them becomes condensed and forms an intensely staining mass of lymphoid tissue, L.-gl'. Both artery and

vein are surrounded by this tissue, but the vein seems more deeply embedded. The lymphoid tissue extends for some distance along these vessels and forms a second nodular swelling, *L.-gl.* The position of these swellings may be determined by the small branches of the blood vessels, *y* and *z*, which they accompany. The main mass of lymphoid tissue, *L.-gl.*, forms a lenticular nodule bulging into the perivascular lymphatic; it has been exposed by removing a part of the wall of the lymphatic vessel. In the photograph, Fig. 5, the dark

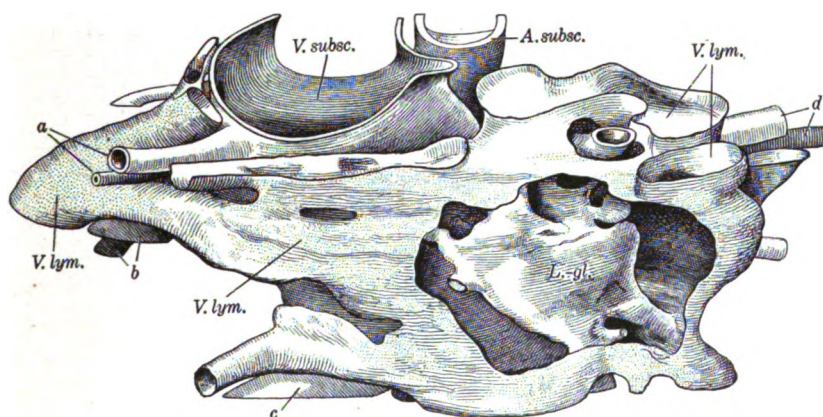


FIG. 12.—Wax reconstruction of the axillary gland of the rabbit shown in Figs. 6 and 10 A. $\times 56$ diams. *A. subsc.*, *V. subsc.*, subscapular artery and vein; *V. lym.*, perivascular lymphatics; *L.-gl.*, lymph gland; *a*, *b*, *c*, *d*, the blood vessels correspondingly lettered in Fig. 10 A.

oval area is *L.-gl.* of the model, and the somewhat triangular mass above it is *L.-gl'*; in the midst of the latter the vessel *z* may be seen. Fig. 5 is therefore a horizontal section of the model. The fact that there are two nodular masses of lymphoid tissue connected with one another suggests the twin glands (*Zwillingsdrüsen*) which Kling regarded as malformations due to incomplete subdivision. The bulging of the lymph gland *L.-gl.* into the lymphatic vessel recalls the following observation by Ranvier:⁷ "Whenever I have observed a vascular nodule on a lymphatic, the latter has appeared to be interrupted.

⁷Ranvier, L., *Morphologie et développement du système lymphatique*. Arch. d'anat. mic., 1897, vol. 1, pp. 137-152.

. . . . Thus, the lymphatic, divided at the level of the nodule, forms two trunks, of which the inferior becomes an afferent and the superior an efferent. If a new gland forms along the course of the efferent the latter will become the afferent for the second gland. The efferent for one gland may be the afferent for another."

The subscapular gland of the rabbit is shown in the model, Fig. 12. The subscapular vein and artery are spun about with perivascular lymphatics, which extend along the branches of the blood vessels, *a*, *b*, *c* and *d*. (Compare with Fig. 10A.) The lymph gland *L.-gl.* is seen through a window cut in the lymphatic vessel. It rests upon the subscapular vein and bulges into the lymphatic, pushing the endothelium before it. That the gland is more intimately related to the vein than to the artery is shown in Fig. 6. The upper portion of the gland is irregularly subdivided, so that in one or two sections there is a suggestion of the plexus formation; lower down it forms a single rounded mass.

In addition to the well-defined gland in each axilla, other glands were found in the thoracic region of both the human and rabbit embryos. In the human embryo there is indication of lymphoid tissue along the dorsalis scapulae vessel and a somewhat diffuse gland near the anterior end of the internal mammary vein. Where the pleuro-pericardial septum joins the diaphragm a branch of the internal mammary vein passes inward, accompanied by a large lymphatic. Near the junction of the septum and diaphragm lymphoid tissue is found in relation with these vessels. The left pleuro-pericardial septum is thinner and farther from the median line than the right and has no corresponding lymphoid tissue. In the rabbit there is a developing gland along the thoraco-epigastric, or external mammary vein, nearly opposite the elbow.

The glands of the head and thorax have now been described; the abdominal and pelvic regions remain to be considered. In four rabbit embryos of 29 mm. a gland was found along the ilio-lumbar vein on either side of the body. It appears to be smaller than the axillary gland, but has essentially the same features. It is more deeply placed than the other glands. The ilio-lumbar vessels (Fig. 10B) have extensive subcutaneous branches, *f*, *f*, *f*, and a branch, *e*, to the abdominal

musculature. As noted by Krause, the ilio-lumbar vessels are highly developed in the rabbit. The lymph gland is found, as shown in Fig. 10*B*, where the subcutaneous branches join the main stem.

In the abdominal part of the human embryo of 42 mm. no distinct glands were found, but along the femoral vessels, in the inguinal region, there is a suggestion of lymphoid tissue. At 50 mm. Miss Sabin describes the posterior lymph sacs as lying in the side of the pelvis opposite the first three sacral vertebrae, and states that "the entire dorsal wall of the sac is occupied by a lymph node" (1909, p. 87). A gland which extends over three sacral vertebrae is clearly unlike any gland in the adult. The structure referred to seems to be the plexus of deep lymphatics, among which lymphoid tissue has appeared, but has not yet formed glands. At this stage Miss Sabin speaks of "secondary nodes" developing near the sacs along the femoral and sciatic groups of veins. In an 80 mm. embryo she describes a true lymph gland which, from its structure and position, as shown in a figure, strikingly suggests the ilio-lumbar gland of the rabbit; it is not stated along what vessels it occurs. The description of the gland is as follows: "In Fig. 19 is a tiny lymph node . . . which illustrates well the simplest form of a lymph node, a central mass of lymphocytes with a plexus of lymph ducts around it. This plexus of ducts is so close that it may already be termed a sinus, so that the node consists of a single follicle with its peripheral sinus." It may be noted that Miss Sabin has figured such a simple gland in the lung of an adult pig (1905, p. 385), and Kling has described them in the axilla of an adult man.

From the preceding study the conclusion may be drawn that the first definite lymph glands are superficial. They appear with surprising regularity, as shown by comparing the three rabbit embryos of 29 mm. They are situated along the large cutaneous veins, and there is a well-developed pair for the head, thorax, and abdomen respectively. In addition to these, the rabbit embryo of 29 mm. gives evidence of gland formation along the thoraco-epigastric vein. The human embryo of 42 mm. differs from the rabbit of 29 mm. by the absence of the ilio-lumbar gland and the presence of the submental gland, together with indications of glands along the internal mani-

mary and femoral veins. Doubtless, both in man and the rabbit the development of additional glands proceeds rapidly.

At the time when the superficial glands are distinct the deep ones are represented by lymphoid trabeculae, which are said to be transformed into chains of glands by the accumulation of the lymphoid tissue in nodules. Something of this sort must occur, but models showing the development of such a chain have not yet been made. It seems undesirable to speak of an extensive plexus of lymphatic vessels, even when associated with diffuse lymphoid tissue, as a lymph gland.

At the time when the lymph glands and trabeculae arise—that is, in the embryos which have now been described—there is apparently no lymphoid tissue elsewhere in the body. The spleen is well developed, but the compact tissue of which it is composed does not appear like that of the lymph glands. The thymus at this stage, in the rabbit at least, is clearly an epithelial organ. This is contrary to the statement of Gulland,⁸ that “the thymus in mammalian embryos is the first place where true adenoid tissue is formed, and it is an active center for the production of leucocytes long before lymphatic glands are formed at all.”

The question of the origin of lymphocytes can be answered only by examining thin and specially stained sections. The embryos here described were prepared for general study, and the sections are 10 microns or more in thickness. They suggest, however, that the lymphocytes are forming in the glands and that they are absent from the blood. Maximow, who has studied the embryonic development of the blood with faultless technique, has unfortunately not examined the earliest lymph glands.⁹ He considers that “the first leucocytes, the lymphocytes, arise at the same time and from the same source as the primitive erythroblasts. The latter represent a specially differentiated form of cell, but the lymphocytes always remain undifferentiated.

⁸Gulland, G. L., The development of lymphatic glands. *Journ. of Path. and Bact.*, 1894, vol. 2, pp. 447-485.

⁹Maximow, A., Untersuchung über Blut und Bindegewebe. I. Die frühesten Entwicklungsstadien der Blut, etc. *Arch. f. mik. Anat.*, 1909, vol. 73, pp. 444-561.

Therefore, like the primitive blood cells from which they directly proceed, they are undifferentiated rounded amoeboid mesenchymal cells." He states that these lymphocytes of the embryo "have nothing to do with lymphoid tissue"—they develop in the yolk sac.

The lymphocytes of the lymph glands are, indeed, round mesenchymal cells, but, except for an occasional cell in the lymph sinus, apparently detached from the gland, they are unlike the forms of corpuscles in the adjacent vessels. It seems probable that the lymph glands, arising in rabbit embryos of 25-30 mm. and in human embryos of 30-45 mm., are the source of a special form of round mesenchymal cell, which is the true lymphocyte. This opinion can be established or disproved only by a cytological study of the early lymph glands, the position of which has been indicated.

BOOK REVIEWS.

AN ATLAS OF SKIAGRAMS. Illustrating the Development of the Teeth, by Johnson Symington, M.D., F. R. S., Belfast. Longmans, Green & Co., London, Publishers.

An entirely new method of presenting the development of the temporary and permanent sets of teeth has been brought out by Dr. Johnson Symington, of Belfast, in a series of Röntgen ray pictures taken of the skulls of children of various ages. The skiagrams, twelve in number, have been made from eighteen children, ranging in ages from birth to sixteen years, and one adult.

In the preparation of the charts, the skulls were split in half through the median line, one-half being laid on a photographic plate, and the Röntgen rays applied from above. The plates thus made were developed full size, without any retouching or correction. In addition to these five drawings were made of dissections of certain of the skulls, in relation to the position and size of the maxillary sinus, the drawing being life size. Accompanying all of the charts and drawings there is a short description of findings appended to each.

Upon examination of the work the most striking characteristic is the excellence of the skiagrams and the remarkable clearness of their detail. The developing teeth are clearly shown, lying in crypts in the bone, and their relation at each stage can be determined. In the early cases, the beginning of enamel formation is very picturesquely shown, the first formation being in the tips of each cusp, and in the multicuspid tooth a union of the enamel from the several cusps occurs, forming the whole crown.

The growth of each tooth may be traced through its various stages, from beginning to completion. This is especially true in the lower jaw, in which the teeth are more distinctly shown than in the upper. In the upper jaw, the bones of the face more or less obscure the outline of the teeth. In this respect, the extent to which the tooth is formed at the time of its eruption may be clearly seen—so also, the time of complete calcification of the roots, with the

closure of the apical ends of the root canals, can be easily determined.

The relation of the forming permanent tooth to the corresponding temporary one, which it is to supplant, is every nicely brought out, showing the amounts of calcification of the permanent tooth at various ages, and at the same time the amounts of resorption of the temporary tooth. In the case of the permanent molars, which do not supplant any of the temporary teeth, their relation to the jaw and to the teeth present is very interesting, inasmuch as the direction of growth and exact position in jaw can be very clearly made out. An excellent opportunity is offered in these charts for the study of the relations of the teeth, both temporary and permanent, in regard to the lateral pressure which they exert in their growth, and its effect upon the widening and elongation of the dental arch.

In several instances, in these figures, there has been a loss of the temporary tooth before the corresponding permanent one was sufficiently developed for eruption, and the subsequent dipping of the adjacent teeth and tendency to close the space is clearly shown. In one individual, both lower first molars were lost, and the roots, which were remaining in the jaw after the destruction of the tooth by caries, have become exfoliated to the surface, and below them is shown a marked condensation of the bony structures.

There is little of corollary work, with which this treatise may be compared, outside of the dissections made of the skulls of children, with a removal of the outer plate of the jaws, uncovering the developing teeth in position, or photographs of the same. Although this atlas is scarcely as efficient in its presentation of the subject as the actual dissections, it certainly excels any manner of photograph or text illustration which we have. The views are more comprehensive than any single plane photograph can be. So that the figures made are very commendable for text illustration, and the atlas in itself will be of great service in presenting the subject both to student and to practitioner.

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Received for publication, March 15, 1909.

A STUDY OF THE CAUSES UNDERLYING THE ORIGIN OF HUMAN MONSTERS. Franklin P. Mall, Jour. of Morph., Vol. XIX, Feb., 1908.

The recent publication by Mall on the causes underlying the origin of human monsters marks an epoch in the study of teratology in this country, for he has treated the subject with a breadth of view and a wealth of illustration rarely found in the handling of this complex question. Mall has brought to the task a profound knowledge of the older literature of the subject, an appreciation of the most modern results in experimental teratology, and a thorough familiarity at first hand with the subject of human monsters. The physician and anatomist are brought into close touch with the work generally supposed to be outside of their proper field; and on the other hand the student of malformations in the lower animals will be made to appreciate the inexhaustible supply of human materials with which the anatomist and physician are familiar. Mall's material consisted of 163 pathological human embryos that include nearly all of the commoner forms of human abnormalities. He points out, that from the earliest ages the study of monsters and the causes that produce them have been two of the capital problems of anatomy, medicine and natural history; that the ancient belief of their supernatural causes has been replaced in part by the theory of maternal impressions; that this belief also has gradually been replaced in turn by the theory that monsters are germinal or else produced by external causes adverse to the normal development of a normal germ cell. Recognizing that some of the monstrous forms may be germinal, Mall argues with great ability that the great majority of monsters such as anencephaly, spina-bifida and cyclopia are due to external agencies affecting the germ, chief amongst which he recognizes faulty implantation of the embryo in the uterus. Faulty implantation by interfering with the nutrition of the embryo is recognized as the chief mechanical factor in producing the result. When it is recalled that the human ovum is extremely small at its beginning, that it is without a store of yolk and must depend for its growth on materials absorbed from the mother through the placenta, there can be little

doubt that Mall has indicated the chief sources of abnormal development. On the other hand, nutrition *per se* is probably not the only cause, for an abnormal condition of the uterus implies the formation of injurious substances, and these, aside from nutrition, may affect the normal sequence of changes. Mall recognizes in fact such conditions as another source of imperfection. He is less favorably inclined to the supposed influences of adhesions, strangulations and the like, and suggests that such fusion and restraints are of secondary rather than of primary importance. To the reviewer it seems that too little weight is attached to these factors, although it is clear that too great weight has often been given to them, and on the whole Mall has done good service in drawing attention away from these towards the other more prolific sources of malformations. Mall's observations that "in very early stages the amnions and embryos are equally susceptible, and the umbilical vesicle and chorion are the most resistant" while "later it is the embryo alone and still later the head, central nervous systems and extremities" that are most affected is a generalization of great importance.

It is pointed out that, while the earlier of the modern teratologists were first inclined to the view that polyspermy is the cause of double monsters, later researches have rendered this view improbable. The early separation of embryonic cells has been shown to produce directly double structures. Almost identical results have been obtained, however, by artificial constriction of later stages. In passing it is also interesting to note that results, externally indistinguishable, may be also produced by chemical reagents.

From details in Mall's monograph concerning pathological ova in relation to the conditions in the uterus; for the cases in which successive births have given rise to pathological embryos; for the relation between tubal pregnancies and abnormalities, etc., the reader must be referred to the able treatment of the problems involved. There is open here a wide field for experimental study on lower mammals where the conditions might be artificially induced.

Following the custom of human embryologists Mall speaks of the earlier embryos and their membranes as ova—a term that will not recommend itself to the student of general embryology, for here the ovum has a distinct and definite meaning.

The embryos that Mall has studied are grouped according to "weeks" from the second to eighth week. It is impossible in a brief review to do justice to the interesting facts here considered. In all, 138 pages are devoted to this general treatment of the problem; the remaining 223 pages give the data for the individual cases considered.

This great monograph on human teratology should excite widespread interest in this important field of anatomy. The standard here set in the treatment of the questions involved is certain to have a beneficial result on the study of normal and pathological anatomy in this country.

T. H. Morgan.

Received for publication, March 22, 1909.

NOTES.

Dr. S. Walter Ranson will have charge of the work in anatomy at the Northwestern University Medical School.

In the department of Anatomy in the University of Virginia, Professor H. E. Jordan, formerly Adjunct Professor, has been advanced to the rank of Associate Professor. Mr. J. A. Waddell, A. B., has been appointed Instructor in Anatomy.

Dr. Arthur W. Meyer has been appointed Professor of Human Anatomy in the Leland Stanford Junior University of California. He is to have charge of the gross anatomy, physical anthropology and human embryology, the work being given at Palo Alto. The histology is given by Professor McFarland, the neurology by Assistant Professor Stoltenberg, while the general embryology is given in the department of zoölogy.

In the University of Missouri Dr. Caroline McGill is to have a year's leave of absence to accept the fellowship in anatomy awarded her by the Naples Table Association for Scientific Research. She will spend the summer working in the laboratory at Woods Hole and in the fall will go abroad, where she plans to work at the universities of Berlin and Tübingen.

Mr. L. G. Lowrey has been appointed assistant in anatomy.

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ON THE DEVELOPMENTAL TOPOGRAPHY OF THE THORACIC AND ABDOMINAL VISCERA.

BY

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From the Anatomical Laboratory, University of Missouri, Columbia.

WITH 26 FIGURES AND 1 TABLE.

The purpose of the present paper is to describe the principal changes in position which the viscera undergo during the process of development, and to discuss some mechanical principles involved in these changes. The materials used include a considerable number of human embryos and fetuses in my collection. Several of these are cut in serial sections, and from four of them models were reconstructed by Born's wax-plate method. The embryos modeled are No. 60 (5th week, 11 mm. crown-rump length), No. 58 (6th week, 17 mm. crown-rump length), No. 57 (8th week, 31 mm. crown-rump length), and No. 55 (12th week, 65 mm. crown-rump length). I am greatly indebted to several of my students for assistance in reconstructing these models. That of No. 60 has already been described by Bonnot and Seevers.¹ The model of No. 57 was in large part reconstructed by C. B. Rodes, Jr., and that of No. 55 by A. W. Kampschmidt and F. O. Kunz. The volumes of the various organs and parts of these embryos (excepting No. 55) have been given by me in another paper.²

¹Anatomischer Anzeiger, Bd. 29, 1906, S. 452-459.

²American Journal of Anatomy, Vol. VIII, No. 1, 1909.

The models are especially designed to show the topographic relations of the thoracic and abdominal viscera to the skeleton, the projections of the sternum, ribs and vertebral centra being indicated upon the underlying organs in the models as shown in the various figures. In order to show the general position and relations of the organs represented in the models, with reference to the body as a whole, graphic reconstructions were made (Figs. 1 to 4) showing from the left lateral view the outlines of the body, ribs, sternum, vertebral column, etc. The parts corresponding to the models are indicated in the figures by the shaded (stippled) areas.

In the following paper, the general relations of the viscera to the body wall, particularly to the vertebral column, will be discussed first, followed by a brief consideration individually of the principal viscera.

RELATIONS TO THE VERTEBRAL AXIS.

The most striking and important feature in the relations of the viscera to the vertebral column in the embryo is the so-called migration of the various organs along the body axis during the course of development. This phenomenon, which is of general occurrence among the higher vertebrates, has long been known, but its cause has never been fully and satisfactorily explained.

In general, we recognize that the migration of an embryonic organ may be either active or passive in character. An active migration is due to the (amœboid?) movement of the component cells, *e. g.*, of the early anlagen of the sympathetic ganglia. It therefore does not require actual growth (increase in volume) of the parts concerned. Passive migration, on the other hand, is produced by pressure or tension due to unequal growth, relatively more or less rapid, either in the organ displaced or in neighboring organs or parts. It is evident that the migration of the viscera along the body axis belongs to the latter class. This principle was recognized by His,³ who was the first to investigate in a systematic way the subject of developmental mechanics.

³Unsere Körperform, Leipzig, 1874; also in Archiv f. Anat. u. Entw., 1894, S. 1ff.

His recognized that the heart and other organs which lie far forward on the ventral side of the embryo at a very early period are at first pushed backward (caudad) by the ventral flexure of the body axis in the head region. Up to the third week in the human embryo, while the body axis remains comparatively straight, the heart lies chiefly ventral to the head region. During the third and fourth weeks, owing to the flexures in the head region,—the primary cephalic flexure opposite the midbrain, and the cervical flexure at the junction of the head and neck—the heart and adjacent organs are pushed backward farther and farther. In the fifth week (Fig. 1), at the close of the period of greatest flexure of the body axis, the heart lies entirely opposite the cervical region of the vertebral column. It is difficult to determine with certainty the exact vertebral level of the various organs at this period, on account of the extreme flexure of the body.

The cause of this flexure ventralward of the body was originally explained by His as due to the restraint of the amnion upon the elongating embryo; but it is now generally believed to be due to the early overgrowth of the central nervous system, lying dorsal to the body axis. Later, when the structures lying ventral to the body axis begin to expand more rapidly, the head becomes more erect and the cervical flexure is largely obliterated.

The influence of the brain and spinal cord in producing the flexure of the body is well shown in embryos with anencephaly and spina bifida. In the absence of brain and spinal cord, the ventral flexure of the body axis is reduced or absent. An anencephalic embryo of about two months (27 mm. head-trunk length) in my collection shows no ventral flexure of the body axis. The axis is nearly straight, the face being directed ventralward. In older fetuses of this character, as is well known, the face looks upward as well as forward, giving the so-called "frog-face" expression. In a mid-sagittal section of such a fetus, I find the base of the cranium making an angle dorsalward at the junction with the vertebral column, instead of ventralward as in the normal condition. This is evidently due to the unopposed expansion in the facial region, not meeting the normal resistance of the cranial contents. A study of younger embryos (first

and second months) of this class ought to throw more light upon the relation of the growth of the central nervous system to the production of the body flexure. This much is certain, however, that the absence or rudimentary condition of the brain and spinal cord (at least in the later stag^s) does not prevent the descent of the thoracic and abdominal viscera; for I find these organs at approximately their normal vertebral levels in fetuses with this deformity.

A study of the relations in the normal embryo leads to a similar conclusion. However important the ventral flexure of the body axis may be in displacing the heart and other organs in the early embryo, it is certain that this is not the only factor involved. At the end of the period of greatest flexure, as seen in the 11 mm. embryo (Fig. 1), the viscera still lie far above (*i. e.*, cephalad to) their permanent levels. The continued descent of the viscera along the vertebral column is clearly apparent when Figs. 1, 2, 3, and 4 are compared. His⁴ also recognized that the displacement of the viscera is only in part accounted for by the ventral body flexure. The final displacement was explained as an *apparent* migration of the viscera downward along the body axis. He states that in reality the cervical portion of the spinal cord (and column) undergoes a relative elongation about the sixth week, so that it actually pushes upward into the head region, thus moving apast the ventral viscera, which are left lying opposite a lower level on the vertebral column. The neck prominence (Nackenhöcker) characteristic of this period he explained as due to this pushing upward of the cervical portion of the spinal cord.

On closer examination, however, there appears no valid evidence to support this view. In fact, His's own figures show no relative elongation of the cervical portion of the spinal cord or vertebral column at this time. On the contrary, there is during this period a constant decrease in the relative length of the cervical region, at least in the vertebral column. In order to show more exactly the growth in relative length in the various regions of the vertebral column during

⁴Anatomie menschl. Embryonen, I, S. 78; III, S. 120 ff. Cf. also Archiv f. Anat., 1881, S. 319.

prenatal life, I have arranged Table I, based upon my own observations and those of Aeby,⁵ His,⁶ Merkel,⁷ Bardeen,⁸ and Ingalls.⁹

In Table I, the cervical region in embryos under 10 mm. (before the vertebræ are well differentiated) includes the eight cervical somites. There is evidently a constant decrease in the relative length of the cervical portion of the column, with a corresponding increase in the lumbar region, as was first shown by Aeby (*l. c.*). The change, as may be seen in the table, is most rapid in the first six weeks. During this time the cervical region decreases from about 35 per cent to about 30 per cent of the length of the cervico-thoraco-lumbar division of the column. The lumbar region increases at the same time from about 17 per cent to about 22 per cent. During the remainder of the entire fetal period, the cervical region decreases from about 30 per cent to about 25 per cent; while the lumbar region increases from about 22 per cent to about 27 per cent. Aside from individual variations, the relative length of the thoracic region remains fairly constant (average about 48 per cent). The sacral region at the beginning increases in relative length, reaching approximately its permanent relation (individual variations excepted) about the end of the first month. The coccygeal region apparently reaches its maximum relative length in the second month, though it is exceedingly variable.

But even if there were, as His supposed, a relative elongation of the cervical region of the vertebral column in the second month, this would not account for the migration of the viscera downward along the *thoracic* as well as the cervical vertebræ. So it is evident that some other cause must be sought. And that cause, it seems to me, is in general the relatively more rapid growth beginning at this time in the structures lying ventral to the body axis. This may be noted particularly in the cervico-facial (pharyngeal) region, as may be seen by comparing Figs. 1, 2, 3, and 4. The relatively rapid ex-

⁵Archiv f. Anat. u. Entw., 1879.

⁶Anatomie menschl. Embryonen, I, S. 97.

⁷Menschliche Embryonen auf Medianschnitten untersucht. Göttingen, 1894.

⁸American Journal of Anatomy, Vol. IV. p. 277, 1905.

⁹Archiv f. mikr. Anatomie, Bd. 70, 1907.

TABLE I.

Relative Length of the Various Regions of the Vertebral Column in the Human Embryo and Fetus, expressed in Percentage of the Cervico-Thoraco-Lumbar Division. (Percentage of the Entire Column in Parentheses.)

Observer.	Crown-Rump Length. Mm.	Total Length of Column Mm.	Cervical Region. Per Cent.	Thoracic Region. Per Cent.	Lumbar Region. Per Cent.	Sacral Region. Per Cent.	Coccygeal Region. Per Cent.
His.....	4.	7.9	35.1(28.5)	47.7(38.6)	17.2(13.9)	12.5(10.1)	10.9(8.9)
Ingalls.....	4.9	5.4	36. (31.)	46. (40.)	18. (15.)	12. (11.)	4. (3.)
Bardeen.....	7.		30.7	50.8	18.5	14.	
Aeby.....	7.	10.5	34.5(28.1)	45. (36.7)	20.5(16.7)	[22.8(18.6)]	
Bardeen.....	7.5	8.75	30.8(22.9)	49.2(36.6)	20. (14.9)	19.2(14.3)	15.4(11.4)
His.....	7.5	11.9	35. (26.5)	44.4(33.6)	20.6(15.5)	20.6(15.5)	11.1(8.8)
Aeby.....	10.	11.73	30.5(25.6)	46.7(30.2)	22.8(19.2)	[18.3(16.0)](?)	
Bardeen.....	11.	9.9	31. (23.1)	46. (34.2)	23. (17.1)	19.5(14.5)	14.9(11.1)
Jackson.....	11.	12.2	31.9(23.8)	48. (35.7)	20.1(15.)	18.7(14.)	15.3(11.4)
His.....	13.	12.	30.5(25.)	46.7(38.3)	22.8(18.7)	13.7(11.3)	8.1(6.7)
Bardeen.....	14.	10.14	29.9(22.7)	47.1(36.5)	22.1(16.8)	17.4(13.2)	14.3(10.8)
Bardeen.....	16.	12.1	31.7(24.)	47.5(35.9)	20.8(15.7)	17. (12.8)	15.4(11.6)
His.....	16.	12.55	30.6(23.9)	46.9(37.1)	22.5(17.9)	17.8(13.9)	9.2(7.2)
Jackson.....	17.	13.	31.1(24.1)	50. (38.7)	18.9(14.6)	17. (13.1)	12.2(9.5)
His.....	21.5	16.7	29.3(23.4)	47.4(37.7)	23.3(18.5)	17.3(13.8)	8.3(6.6)
Bardeen.....	22.	18.84	29.2(23.)	47.2(37.2)	23.6(18.6)	18.9(15.)	8.1(6.4)
Jackson.....	23.	16.7	27.9(23.2)	51.5(42.7)	20.6(17.1)	14.0(11.6)	6.6(5.5)
Bardeen.....	30.	22.78	29.3(23.7)	49. (39.5)	21.7(17.5)	16.3(13.2)	7.5(6.1)
Jackson.....	31.	22.6	30.8(24.3)	47.9(37.8)	21.3(16.9)	18.8(14.9)	7.8(6.1)
Bardeen.....	33.	22.9	28.9(22.3)	48.5(37.3)	22.7(17.5)	19.8(15.3)	9.9(7.6)
Jackson.....	35.	29.9	26.1(21.)	49.1(31.5)	24.8(20.)	18.2(14.6)	6.1(4.9)
Merkel.....	43.	33.	27.7(22.)	48.2(38.3)	24.1(19.1)	18.8(14.9)	7.1(5.7)
Bardeen.....	46.	38.75	27.9(21.3)	47.5(36.1)	24.6(18.7)	18.6(14.2)	12.7(9.7)
Bardeen.....	50.	34.65	29.2(23.1)	47.5(37.5)	23.2(18.3)	17. (13.4)	9.7(7.6)
Aeby.....		45.	28.2(22.2)	47.9(37.8)	24. (18.9)	[26.8(21.1)]	
Jackson.....	65.	58.	25.4(19.7)	48.3(37.4)	26.3(20.4)	18.4(14.3)	10.5(8.2)
Merkel.....	73.	50.	25.5(20.1)	50. (39.6)	24.5(19.4)	17.8(14.2)	8.5(6.7)
Merkel.....	89.	60.	28.1(22.5)	46.6(37.2)	25.3(20.1)	18.4(14.7)	6.8(5.4)
Aeby.....		74.7	25.6(20.1)	48.7(38.1)	25.6(20.1)	[27.7(21.7)]	
Aeby.....		91.	26.1(20.6)	48.2(37.9)	25.6(20.1)	[27.3(21.4)]	
Aeby.....		91.	26.4(20.9)	48.6(38.4)	25. (19.8)	[26.4(20.9)]	
Aeby.....		91.	25.5(20.9)	49. (40.1)	25.5(20.9)	[22.2(18.1)]	
Merkel.....	140.	101.	24.5(19.3)	50. (39.3)	25.5(20.)	17.9(14.1)	9.4(7.4)
His.....	143.	101.	28.9(21.8)	47.4(35.7)	23.7(17.8)	21.1(15.8)	11.8(8.9)
Merkel.....	170.	123.	25.9(20.)	48.2(37.2)	25.9(20.)	19.6(15.2)	9.8(7.6)
Jackson.....	190.	128.	24.5(19.5)	50. (39.9)	25.5(20.3)	20.6(16.4)	5. (4)
Jackson.....	205.	137.	23.9(19.)	48.6(38.9)	27.5(21.9)	18.3(14.6)	7.3(5.8)
Jackson.....	210.	137.	25. (20.4)	48.7(40.1)	26.5(21.9)	16.8(13.9)	4.4(3.7)
Aeby.....		140.5	22.1(20.9)	49.6(38.4)	28.3(19.8)	[24.3(20.9)]	
Jackson.....	265.		24.	48.6	27.4		
Merkel.....	310.	208.	22.9(17.)	50.5(37.6)	26.7(19.9)	21.9(16.3)	12.4(9.2)
Jackson.....	320.		24.5	48.5	27.		
Jackson.....	340.		23.9	48.9	27.2		
His.....		227.	23.6(18.5)	50.6(39.6)	25.8(20.3)	19.7(15.4)	7.4(6.2)
Merkel.....	365.	247.	20.6(15.3)	52.9(39.4)	26.5(19.8)	22.5(16.8)	11.8(8.8)
Aeby (average of 8 newborn).....		221.5	25.6(20.4)	47.5(37.9)	26.8(21.4)	[25.4(20.3)]	
Aeby (average of 13 adults).....		738.	21.5(17.0)	46. (36.4)	32.3(25.4)	20. (15.8)	6.75(5.4)

pansion in this region exerts pressure in all directions. The pressure upward against the massive head, on account of the great resistance, produces comparatively little displacement. The effect is merely to straighten out to a large extent the cephalic and cervical flexures. (The exception in Fig. 4 is only apparent, the cervico-cephalic angle being in reality less marked than in the preceding stages.)

The effect of this expansion in the cervico-facial region is much more marked in the caudal direction, however, where there is relatively more room and the resistance is less. As I have shown in a previous paper (l. c.), the alimentary tract, respiratory tract, and in fact most of the organs lying ventral to the body axis (excepting the heart) are also expanding with relatively great rapidity at this time. Thus in the profile views of His,¹⁰ the œsophagus in the 5.5 mm., 7 mm., 10 mm., and 12.5 mm. embryos is found to equal in length about 25 per cent of the body length. In the 13.8 mm. embryo it has suddenly increased to about 40 per cent of the body length. At the same time the respiratory tract (larynx, trachea and lung) increases from about 20 per cent to about 33 per cent of the body length. The stomach similarly increases in relative size and length. The pyloric end becomes fixed at about the 12.5 mm. stage, hence further relative elongation of the œsophagus and stomach increases the obliquity of the stomach in later stages.

During the second month, this period of relatively rapid growth of the viscera is nearly ended. We find accordingly that in the 17 mm. embryo (Fig. 2), and especially in the 31 mm. embryo (Fig. 3), the viscera have reached nearly their permanent vertebral levels, there being relatively little descent after that time. We shall find similarly that the other topographic changes are also most rapid during the first two months. For purposes of developmental topography therefore the prenatal term may be divided into two periods, corresponding to those already generally recognized. The first or embryonic period includes the greater part of the first two months, during which the changes are most rapid. During the second or fetal period, from the third month onward, the changes in position are relatively slight.

¹⁰Anatomie menschlicher Embryonen, III, S. 16-19.

The visceral branches of the aorta, particularly the cœliac and mesenteric, follow their corresponding viscera downward by acquiring successively new roots of origin from the aorta. This was shown first by Mall,¹¹ later by Tandler¹² and Broman,¹³ according to whom these arteries reach their permanent levels of origin during the second month. The nerves, on the other hand, are unable to shift their attachments to the spinal cord, hence their origin indicates approximately the level of the organ at the time it receives its innervation (*e. g.*, the diaphragm from the 4th cervical).

In addition to the migration caudad along the vertebral axis, the viscera undergo another change in their relation to the vertebral column. In cross sections of the trunk in earlier embryos, the body cavity appears somewhat elliptical in outline (long axis dorso-ventral), and is placed entirely ventral to the vertebral column. Later, as the trunk becomes flattened dorso-ventrally (*cf.* Rodes¹⁴), the body cavity also appears more rounded. At the same time, the vertebral column appears to move forward, forming a median dorsal projection into the body cavity. More accurately stated, the body cavity and viscera extend backward (dorsad) on each side of the vertebral axis. The groove thus formed in the viscera by the vertebral column may be called the vertebral groove.

This change is shown in lateral view in Figs. 1 to 4. In Fig. 1 (11 mm.) the vertebral column lies entirely behind the viscera. In Fig. 2 (17 mm.) the ribs have appeared, but the body cavity and thoracic viscera still lie entirely ventral to the vertebral column, and the dorsal aorta is visible in lateral view. In the abdominal region, on the other hand, the kidneys and suprarenal glands have begun to move backward on each side of the vertebral column, which projects forward into the shallow vertebral groove between them. In the 31 mm. embryo, this groove is much deeper, involving also the lungs, and including about half of the width of the vertebral column as seen in lateral view (Fig. 3). The body cavity and ribs extend still

¹¹Journal of Morphology, Vol. V, 1891.

¹²Anatomische Hefte, Bd. 23, S. 189, 1903.

¹³Anatomische Hefte, Bd. 37, 1908.

¹⁴Zeitschrift f. Morphol. u. Anthropol., Bd. 9, 1905, S. 113 ff.

further backward, the angles of the latter now reaching nearly to the middle of the spinal cord. At 65 mm. (Fig. 4), the groove has become so deep as to include nearly the entire centra of the vertebral column. Corresponding to the width of the vertebral column (centra), the vertebral groove is narrower from side to side in the thoracic region and wider below in the lumbar region (cf. Fig. 20). The pleura at the angles of the ribs extends backward so that in lateral view it covers a large part of the spinal cord (Fig. 4). There is thus formed here (likewise in the 31 mm. and 17 mm. stages) behind the lungs in the pleural cavity a considerable space filled with fluid. In later stages, as the lungs expand the fluid is apparently absorbed, and this space largely disappears. So far as the body cavity is concerned, however, this groove for the vertebral column has nearly reached its permanent relative (fetal) depth at the end of the third month.

The cause of the formation of this vertebral groove in the viscera is in many respects difficult to understand. As previously stated, it cannot be explained as due to a pushing forward of the column, which appears to remain relatively fixed in size and position. The change is rather due to movement in the viscera lying ventral to the vertebral axis. The change in the general form of the body wall (which is much elongated dorso-ventrally in the earlier stages, becoming nearly circular in cross-section about the third month) is readily explained as due to the pressure of the rapidly expanding viscera. Since more resistance is offered by the vertebral column, this pressure may be more effective laterally, thus producing grooves on either side of the vertebral column, so that it projects forward from the posterior body wall. Henke¹² has proposed an ingenious theory explaining the deepening of the vertebral groove in the thorax during childhood as due to a characteristic growth process in the ribs. This theory, however, will hardly apply to the origin of this groove in the embryo, and fails to account for a similar change in the form of the body wall in the lumbar region. Yet it is quite possible that the formation of the vertebral groove is due to growth processes in the body wall not explainable by simple mechanical principles.

¹²Anatomie des Kindesalters, 2. Aufl., Tübingen, 1881, S. 101 ff.

RIBS AND BODY WALL.

As is apparent in lateral views, the ribs, which extend nearly horizontally forward when first formed (17 mm., Fig. 2, and 31 mm., Fig. 3), soon extend obliquely downward and forward. This obliquity is unusually marked in the 65 mm. specimen (Fig. 4). The obliquity of the ribs is due to the fact that they elongate relatively more rapidly than the corresponding body wall. This may also account for the formation of the angles of the ribs and costal cartilages. There is also a depression of the anterior body wall as a whole, however, as is shown by the oblique course of the abdominal nerves, myotomes, etc., at 65 mm. and later stages. The umbilicus, which from the 65 mm. stage onward is found opposite the 4th lumbar vertebra, is located at a higher level in the earlier stages. This is in part, at least, due to a more rapid growth in the anterior abdominal wall, resulting in its relative elongation.

HEART.

As already mentioned, the heart migrates downward (caudad) from its primitive position in the ventral part of the head region. In the 11 mm. embryo (Fig. 1) it lies opposite the 2d to the 7th cervical segment; in the 17 mm. (Fig. 2), opposite the 7th cervical to the 5th thoracic; in the 31 mm. (Fig. 3), opposite the 1st to the 6th thoracic; and in the 65 mm. (Fig. 4), opposite the 4th to the 9th thoracic. In later fetal stages, it usually extends approximately from the 3d to the 8th thoracic vertebra.

At the beginning of the second month, the plane of the diaphragm, between the heart and the liver, extends from above and behind in a direction downward and only slightly forward, nearly parallel with the body axis. The downward displacement of the thoracic viscera takes place more rapidly near the dorsal wall than near the ventral wall, however, so that the heart and diaphragm are apparently rotated on a transverse axis. At 11 mm. (Fig. 1), the diaphragm is rapidly approaching the horizontal position, and at 17 mm. (Fig. 2) has passed it, now extending from behind upward and forward. The direction is similar at 31 mm. (Fig. 3); but at 65 mm. (Fig.

4) the anterior portion of the heart and diaphragm have descended (due to the relative decrease in the size of the liver?) so that the diaphragm has reached a position approximately horizontal.

The long axis of the heart is at first nearly in the mid-sagittal plane, the apex being nearly in the midline at 11 mm. (Fig. 13). It is slightly inclined to the left at 17 mm. (Fig. 14), more so at 31 mm. (Fig. 15), and very decidedly at 65 mm. (Fig. 16). The primitive right side of the heart is thus turned to the front, and the right auriculo-ventricular groove comes to lie behind the sternum near the midline. The asymmetrical position of the heart (which in turn increases the asymmetry of the lungs?) seems to be correlated with the progressive dorso-ventral flattening of the thorax, to which reference has already been made.

The lungs in the 11 mm. embryo lie entirely behind and below the heart, being scarcely in contact with it. (Figs. 1, 5, 9, 1). They gradually extend upward and forward upon the auricles at 17 mm. and 31 mm., and upon the left ventricle at 65 mm. (Figs. 1 to 16).

Although the thymus appears in the 11 mm. embryo, it does not extend down in front of the heart until in the 65 mm. stage (Figs. 4, 16, th), where it is in contact with the upper part of the right auricle and ventricle. In later fetal stages it continues to expand in the anterior mediastinal space, so that it covers to a large but variable extent the anterior surface of the heart in the newborn.

LUNGS.

The lungs arise during the first month from the œsophagus in the mid-cervical region, in the angle behind and between the heart and liver (as seen in reconstructions by His, Mall and others). Until the middle of the second month, the lungs remain comparatively small and retain this primitive position. In the model of the 11 mm. embryo (Figs. 1, 5, 9, 17, 1), the lungs are separated by the œsophagus. They lie on each side in a pocket between the liver and upper end of the Wolffian body below, and arched over by the posterior cardinal vein and ductus Cuvieri above. This pocket is deeper on the right side, which perhaps accounts for the occurrence of an accessory lobe of the lung in this position in the adult more often

on the right side. So far as the vertebral level is concerned, the lungs of the 11 mm. embryo correspond approximately to the position later of the lung apex, lying opposite the last cervical and the first two thoracic segments, and under cover of the anlage of the upper limb. The migration continues downward along the vertebral column, however, so that the lung in the 17 mm. embryo (Fig. 2) lies opposite the 4th-9th thoracic vertebræ, entirely below the upper limb. In the 31 mm. embryo (Fig. 3), the lung has expanded so as to extend from the 1st to the 10th and in the 65 mm. (Fig. 4) lies opposite the 2d to the 11th thoracic vertebra.

Similarly, the bifurcation of the trachea, which arose in the mid-cervical region, has in the 11 mm. embryo descended to the level of the 1st thoracic segment; in the 17 mm. to the 3d thoracic; in the 31 mm. to the disk between the 3d and 4th; and in the 65 mm. to the disk between the 4th and 5th.

The pulmonary arteries in the 11 mm. embryo arise from the ductus arteriosus and descend along the trachea for a considerable distance before reaching the lungs. The distance is relatively less in the 17 mm. embryo, but it is not until the 31 mm. stage that approximately the permanent relation is reached. The change is apparently due, chiefly not to the ascent of the hilum of the lung, but rather to the descent of the heart with the accompanying vessels.

The lungs are relatively small in the 11 mm. embryo, but expand rapidly upward and forward over the auricles in the 17 mm. and 31 mm. stages, reaching the ventricle on the left side at 65 mm. There is little expansion (relatively) in the fetal lung after this time, the anterior borders of the lungs being separated by a wide anterior mediastinal space occupied largely by the thymus. The fetal lungs are relatively largest about the 4th month, when they average 3.3 per cent of the total body volume.

The lobes of the lungs are not distinct in the 11 mm. embryo, but are well marked at 17 mm. The fissures are carried upward and forward by the expansion of the lungs, as may be seen by comparing the relations to the ribs in the various stages (Figs. 1 to 12, l, ls, lm, li). Owing to the large size of the thymus, the cardiac notch is usually not well marked in the fetal lung.

The pleural cavity is from the beginning more extensive than the lung, which at no time fills it completely. In the embryonic stages the pleural cavity always contains a relatively large amount of fluid, which surrounds the lung and distends the cavity. The pressure of this fluid may assist in extending the boundaries of the pleural cavity during the process of development.

In the 11 mm. embryo, the pleural cavities are not yet separated off from the general body cavity. At 17 mm. (Fig. 2, pl) the pleura extends from the 2d to the 9th ribs, and from the plane of the anterior surface of the vertebral column posteriorly nearly to the extremities of the ribs anteriorly. It still communicates with the peritoneal cavity (Fig. 2, pp). In a 24 mm. embryo, and in all later stages, I find the pleura extending from the 1st to the 12th ribs. Anteriorly, however, the pleuræ of the two sides are widely separated, extending forward only to the neighborhood of the internal mammary vessels. They do not approach each other in the anterior mediastinal space until after the atrophy of the thymus in postnatal life. Posteriorly, the pleural cavity in the 31 mm. embryo reaches the plane of the anterior surface of the spinal cord (Fig. 3), and at 65 mm. almost covers the spinal cord in lateral view (Fig. 4).

There is considerable individual variation in the development of the lungs and pleuræ, as well as of other organs. For purposes of comparison, the reconstructions by Mall¹⁶ will be found of especial value.

ALIMENTARY CANAL.

Stomach. The descent of the stomach along the vertebral column has been mentioned previously. In the 11 mm. embryo the cardia lies opposite the 3d or 4th thoracic segment, and the pylorus opposite the 7th or 8th. In the 17 mm. embryo the two ends of the stomach seem to have reached approximately their permanent positions, the cardia opposite the 10th thoracic and the pylorus opposite the 1st or 2d lumbar vertebra. The greater curvature may later extend

¹⁶Archiv f. Anatomie u. Entw., 1897, Suppl. Bd. S. 403-434; also in Johns Hopkins Hospital Bulletin, Vol. XII, 1901, Nos. 121, 122, 123.

much lower, however, especially in cases where the stomach is distended or the liver unusually enlarged.

Superiorly the fundus region is related to the base of the left lung in the 11 mm. embryo (Fig. 1). The liver extends between them in the 17 mm. and 31 mm. stages (Figs. 2, 3, 21, 22), but has retracted at 65 mm. (Fig. 23) leaving this relation constant in all later stages.

Externally the stomach is separated from the body wall in the 11 mm. embryo (Figs. 1, 5, 17, x) by the thick-walled great omentum, in which, in the 17 mm. stage, the spleen appears (Figs. 2, 6, 21, sp). Both are overlapped by the enormous expansion of the liver at 31 mm. (Figs. 3, 22, sp). The stomach is not yet again visible at 65 mm. (Fig. 8), though it is often visible to the left of and below the liver in the later fetal stages.

Anteriorly and to the right, the stomach is at all stages in contact with the posterior surface of the liver (Figs. 17, 21, 22, 23). Posteriorly it is related in the 11 mm. embryo to the left suprarenal gland, sexual anlage, and Wolffian body (Fig. 17). At 17 mm., the pancreas extends across behind the stomach (Fig. 21). Beginning with the 31 mm. stage, the stomach becomes separated from the sex gland and Wolffian body, but comes into more or less intimate relation with the kidneys and intestines (Figs. 22 and 23).

Intestines. The developmental topography of the intestines has been thoroughly worked out by Mall,¹⁷ so that it is unnecessary to describe in detail the relations shown in my models, and indicated in the various figures.

PANCREAS.

The developmental topography of the pancreas has been described by me in a previous paper,¹⁸ to which the reader is referred. Figs. 20, 21, 22, and 24 of the present paper exhibit well many of the relations of the pancreas.

LIVER.

From the beginning, the liver is in intimate relation with the diaphragm, and through this with the heart and lungs. In connec-

¹⁷Archiv f. Anatomie u. Entw., 1897, Suppl. Bd.

¹⁸Anatomischer Anzeiger, Bd. 27, 1905, S. 488-510.

tion with these organs, it undergoes the migration previously described. The upper surface of the liver apparently reaches its permanent level in the fetus at some time between the 31 mm. and 65 mm. stages.

In size, the liver is at first relatively small, but it rapidly enlarges. In the 11 mm. embryo it measured 4.85 per cent of the total body volume (or approximately the same as at birth); in the 17 mm. embryo it has increased to 6.9 per cent; while in the 31 mm. embryo it has reached 10.56 per cent, which represents its maximum relative size. In the 65 mm. specimen the volume of the liver was not measured, but it has apparently decreased to about 5 or 6 per cent, which is the average for the remainder of the fetal period. The importance of the relatively enormous expansion of the liver in producing the characteristic embryonal umbilical hernia has been emphasized by Mall.

The relation of the liver to the body wall and ribs anteriorly and laterally is evident in the various figures, and calls for no special discussion.

The posterior or visceral surface of the liver in the 11 mm. embryo (Figs. 5, 9, 17) is related to the suprarenal gland, Wolffian body and sexual anlage on the right side; to the stomach on the left side; and to the duodenum and head of the pancreas below. At 17 mm., the relations are similar (Figs. 18, 21). At 31 mm. (Figs. 19, 22), the kidneys and spleen come into contact with the liver. The visceral surface at this stage forms a relatively small depression on the posterior surface of the liver. At 65 mm. (Figs. 20, 23) the relations approach those found throughout the remainder of the fetal period. The lower part of the visceral surface is related to the transverse colon and coils of the small intestine. The relations of the liver to the pancreas are described in detail in my paper on the topography of the pancreas (l. c.).

SPLEEN.

The spleen is not well differentiated in the 11 mm. embryo, but the indistinct anlage lies in the thick-walled great omentum in the region of the window shown in the model (Figs. 1, 5, 17, x).

In the 17 mm. stage, the spleen is relatively small but distinct (Figs. 2, 6, 18, 21, sp). It is an elongated prismatic structure, extending from above downward, slightly outward and forward. It has three distinct surfaces (best seen in Fig. 21) corresponding to those of the adult organ. These are: (1) an external surface, corresponding to the (later) diaphragmatic surface, but here in contact with the lateral abdominal wall below the ribs; (2) an antero-internal gastric surface, in contact with the stomach; and (3) a posterior (later renal) surface, here in contact with the left suprarenal, sex gland, and Wolffian duct.

In the 31 mm. stage, the liver has expanded so as to separate the external surface of the spleen from the body wall (Figs. 3, 7, 22). The spleen is here nearly vertical, and in contact antero-internally with the tail of the pancreas, as well as the stomach (Fig. 22, sp). Postero-internally, it is in contact with the left suprarenal.

In the 65 mm. stage, the spleen is relatively larger, but still relatively smaller than in the later fetal stages. It here lies entirely under cover of the ribs. The liver has partly retracted, so that it here covers only the anterior portion of the external splenic surface; the posterior portion being in contact with the diaphragm between the 9th and 10th ribs (Figs. 4, 8, 20, 23, sp). The upper extremity of the diaphragmatic surface is now related to the base of the left lung. Antero-internally and postero-internally the relations are similar to those at 31 mm. The lower extremity of the spleen comes in contact with the splenic flexure of the colon (Figs. 20, 23), a relation which is constant throughout all later stages.

In the later fetal stages, the spleen becomes relatively larger, expanding farther upward, inward and downward. The liver usually retracts somewhat, but is often slightly in contact with the spleen, even at birth. As the suprarenal gland becomes relatively smaller, the posterior surface of the spleen comes into relation more and more with the left kidney. The fetal spleen is constantly related to the base of the lung above, and is usually entirely pre-pleural (as in Fig. 4). The spleen is occasionally enlarged, however, in which case it may extend downward below the lower margin of the pleura.

In position, the longitudinal axis of the fetal spleen is always

oblique, but it usually approaches the vertical more nearly than the horizontal. When the colon is distended, however, the lower extremity of the spleen is flattened and often pushed upward so as to throw the spleen into a position more nearly horizontal.

WOLFFIAN BODIES (MESONEPHROS).

In the 11 mm. embryo, the volume of the Wolffian bodies is .000734 cc. (.6 per cent of the total body volume); at 17 mm., the volume is .00055 cc. (.124 per cent of total body); and at 31 mm., .00045 cc. (.0212 per cent of total body). It is therefore evident that the Wolffian bodies decrease in size, not only relatively but absolutely, from the beginning of the second month.

At the end of the first month, the Wolffian bodies extend from the lower cervical to the lumbar region (according to the observations of His and Mall). In the 11 mm. embryo (Figs. 1, 5, 9, 17, w), they extend along the posterior body wall from the 1st or 2d thoracic segment down to the lower lumbar region, lying just antero-external to the posterior cardinal veins. From the 3d to the 6th thoracic, they are also related internally to the suprarenal anlagen. Anteriorly, they are related to the lungs, stomach, liver and sexual anlagen.

In the 17 mm. embryo (Figs. 2, 6, 10, 18, w), the Wolffian bodies have apparently been drawn downward (being more firmly attached at the lower end), so that they extend from the 10th thoracic to the sacral region. They are separated relatively more widely by the expansion of the kidneys and suprarenals (cf. Figs. 17 and 18, w), and they no longer touch the lungs.

At 31 mm. the Wolffian bodies lie opposite the lower two lumbar and the upper sacral vertebræ. Internally they are related to the ovaries and lower part of the kidneys (Fig. 22a). At 65 mm., the Wolffian bodies appear as rudimentary appendages of the testis, lying opposite the first sacral vertebra (Fig. 20).

SEX GLANDS.

The early developmental topography of the sex glands is very similar to that of the Wolffian bodies, with which they are intimately

connected. They are likewise firmly connected with the body wall below, so that they are also dragged downward during the relative elongation of the lower portion of the trunk in development. In the 11 mm. embryo, the sexual anlagen (sex not yet determinable) form narrow strips extending along the antero-internal aspect of the Wolffian bodies, from the 9th thoracic to the 3d lumbar segment (Figs. 1, 5, sx). The relations are similar to those of the Wolffian bodies in this region. At 17 mm. (Fig. 21a, ov), 31 mm. (Fig. 22a, ov), and 65 mm. (Fig. 20, t), the general position and relations are very similar to those already stated for the Wolffian bodies.

SUPRARENAL GLANDS.

In the 11 mm. embryo, the suprarenal glands (Figs. 1, 5, 17, sr, sl) are rather ill-defined elongated bodies, extending on each side at the level of the 3d to the 6th thoracic segments, between the aorta and the posterior cardinal vein. Anteriorly, they are related to the lungs above, and to the liver (right side) and stomach (left side) below.

In the 17 mm. stage, the suprarenals have descended so as to extend from the 10th thoracic to the 1st lumbar vertebra (Figs. 2, 6, 10, 18, 21a, sr, sl). They are shorter, thicker, and flattened from within outward. Internally they are closely related to each other, being separated posteriorly by the aorta. Posteriorly they are related to the 10th, 11th and 12th ribs below the pleural cavity. Superiorly they are related to the bases of the lungs (Fig. 18). Anteriorly the right suprarenal is related to the liver, the left to the stomach and spleen. Inferiorly they are in contact with the kidneys, and externally with the sex glands and Wolffian bodies.

At 31 mm., the suprarenals (Figs. 3, 7, 11, 19, 22a, sr, sl) extend from the 11th thoracic to the 1st lumbar vertebra. Owing to the change in position of the vertebral column (previously discussed), the suprarenals are separated more widely from each other by the bodies of the vertebræ, and their former internal surfaces are rotated so as to face postero-internally. The aorta is displaced forward, so that it here lies between the anterior margins of the suprarenals. The relations to the body wall, etc., posteriorly are nearly as in the

17 mm. embryo. They do not now extend up to the lungs or 10th ribs, however, although the pleural cavity has extended down behind the upper half of their posterior surfaces. Anteriorly the right suprarenal is in contact with the liver; the left with the stomach and body of the pancreas, and externally with the spleen and left lobe of the liver. Inferiorly and posteriorly, the concave base of each suprarenal is in close contact with the upper portion of the corresponding kidney.

At 65 mm., the suprarenals (Figs. 4, 8, 12, 20, 23a, sr, sl) extend from the 10th thoracic to the 1st lumbar vertebra. They are still more widely separated by the vertebral column, and have rotated so as to lie almost in the frontal plane. They are decidedly flattened antero-posteriorly, and show a distinct groove on the anterior surface (Fig. 23a). The relations are much as at 31 mm., except that the kidneys have pushed up behind them to a greater extent, and the bases of the lungs are again related to them above. The left lobe of the liver has retracted, so that it is no longer in contact with the left suprarenal. The relations of the suprarenal glands found here persist nearly unchanged throughout the remainder of the fetal period.

KIDNEYS.

The kidneys form a notable exception to the general rule in developmental topography, since they migrate upward (cephalad) along the vertebral column, instead of downward like the other viscera. Their relations therefore deserve especial attention.

As is well known, the kidneys (kidney-ureter anlagen) arise as a dorsal outgrowth of the Wolffian duct on each side in the sacral region. By active growth, the anlage elongates, extending forward on each side along the line of least resistance in the loose mesenchyme of the space bounded by the aorta dorsally, the rectum ventrally, and the umbilical arteries laterally.

In the 11 mm. embryo (Fig. 9, u) the T-shaped upper extremity of the anlage (representing the renal pelvis) lies in the upper sacral region, under cover of the wide origin of the umbilical artery. It is extending upward, and is approaching the lower extremity of the Wolffian body. In succeeding stages, as the anlage elongates, the

kidney is pushed upward on either side of the aorta in the loose mesenchyme dorsal and internal to the Wolffian body and sexual anlage.

In the 17 mm. embryo, the kidneys are well developed, with a distinct capsule, and extend from the 1st to the 5th lumbar vertebra (Figs. 2, 6, 10, 18, 21a, kr, kl). They have come in contact with the lower ends of the suprarenal glands, and further extension upward (except to a very slight extent) is possible only later when the suprarenals diminish in relative size. Antero-lateral to the kidney are the Wolffian body and ovary.

At 31 mm., the kidneys (Figs. 3, 7, 11, 19, 22a, kr, kl) still lie below the 12th ribs, extending from the 1st to the 5th lumbar vertebra. Their upper ends reach almost to the lower pleural margin (Fig. 3). The separation and rotation of the kidneys in connection with the changed position of the vertebral column is very similar to that described for the suprarenal glands. Between the kidneys at the floor of the vertebral groove are the aorta and vena cava inferior (Fig. 19, 22a, a, vc). Anteriorly the right kidney is related to the corresponding suprarenal and the liver and ovary below; the left kidney is related to the suprarenal above, and to the liver, pancreas, stomach and ovary below.

At 65 mm. (Figs. 4, 8, 12, 20, 23a, kr, kl), the kidneys have reached approximately their permanent fetal position, extending from the 12th thoracic to the 3d lumbar vertebra. Both kidneys are nearly at the same level, the higher level of the left kidney later being correlated with the atrophy of the left lobe of the liver. Posteriorly the kidneys reach the 12th rib above (and, on the left side, the 11th rib). The pleural cavity covers the upper portion of the posterior surface of each kidney (Fig. 4). Anteriorly the right kidney is in contact with the suprarenal gland above, and with the liver, and small intestines (including the duodenum) below; the left kidney, with the suprarenal above, and the intestines (beginning of jejunum and descending colon) below. The relations of the kidneys found here are but little changed throughout the remainder of the fetal period.

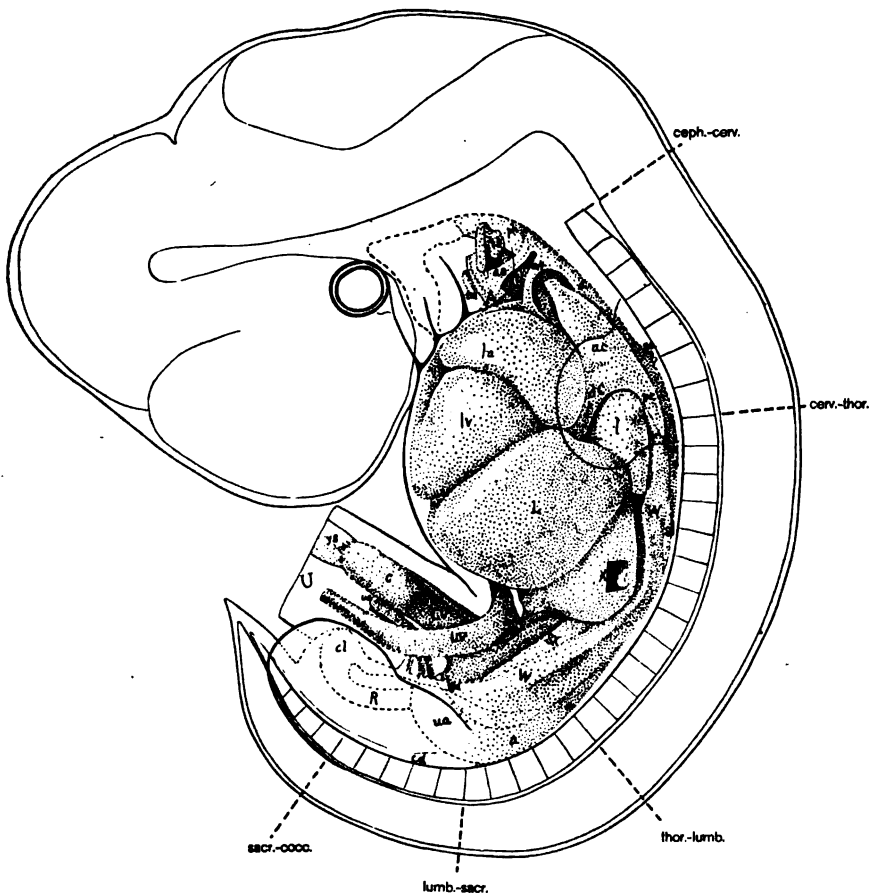


FIG. 1.—Graphic reconstruction of an 11 mm. human embryo (No. 60) from the left side, showing the body outline, extremities, central nervous system, vertebral centra, viscera, etc. The parts corresponding to the viscera in the model (Fig. 5) are indicated by stippling. The various regions of the vertebral column are indicated (ceph.-cerv., cerv.-thor., thor.-lumb., lumb.-sacr., sacr.-cocc.).

A, ascending aorta; a, descending aorta; a3, a4, 3d and 4th aortic arches; ac, anterior cardinal (jugular) vein; c, anlage of the cecum; cd, caudal aorta; cl, cloaca; co, colon; dC, ductus Cuvieri; l, lung; L, liver; la, left auricle; lv, left ventricle; pc, posterior cardinal vein; ph, pharynx; R, rectum; sx, sexual anlage; sl, left suprarenal anlage; sa, origin of subclavian artery; th, anlage of thymus; tl, tm, lateral and median anlagen of the thyroid; U, umbilical cord; ua, umbilical artery; uv, umbilical vein; w, Wolffian body; wd, Wolffian duct; x, window cut into great omentum; ys, attachment of yolk-stalk to intestinal loop.

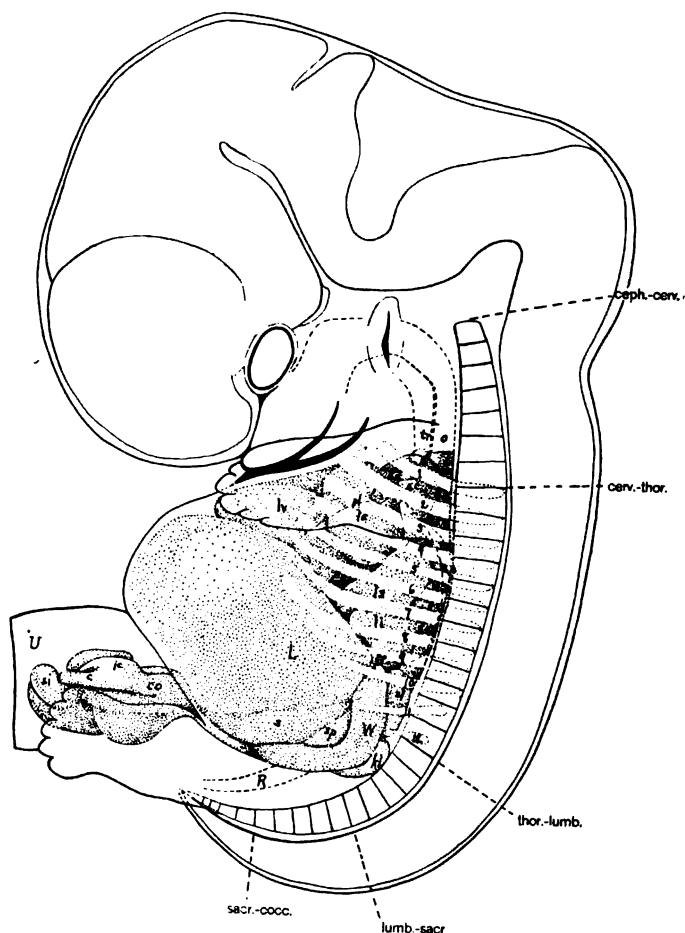


FIG. 2.—Graphic reconstruction of a 17 mm. human embryo (No. 58) from the left side, showing the body outline, extremities, central nervous system, vertebral centra, ribs, etc. The parts corresponding to the wax model (Fig. 6) are indicated by stippling. The various regions of the vertebral column are indicated (ceph.-cerv., cerv.-thor., thor.-lumb., lumb.-sacr., sacr.-cocc.).

a, aorta; ac, anterior cardinal (jugular) vein; c, anlage of cecum and appendix; co, beginning of colon; da, ductus arteriosus; ic, ileo-cecal junction; kl, left kidney; ls, li, superior and inferior lobes of left lung; L, liver; la, left auricle; lv, left ventricle; o, oesophagus; pl, pleural boundary; pp, pleuro-peritoneal foramen; R, rectum, s, stomach; sl, left suprarenal; sl, small intestine; sp, spleen; tr, trachea; U, umbilical cord; w, Wolffian body; 1 to 12, 1st to 12th ribs.

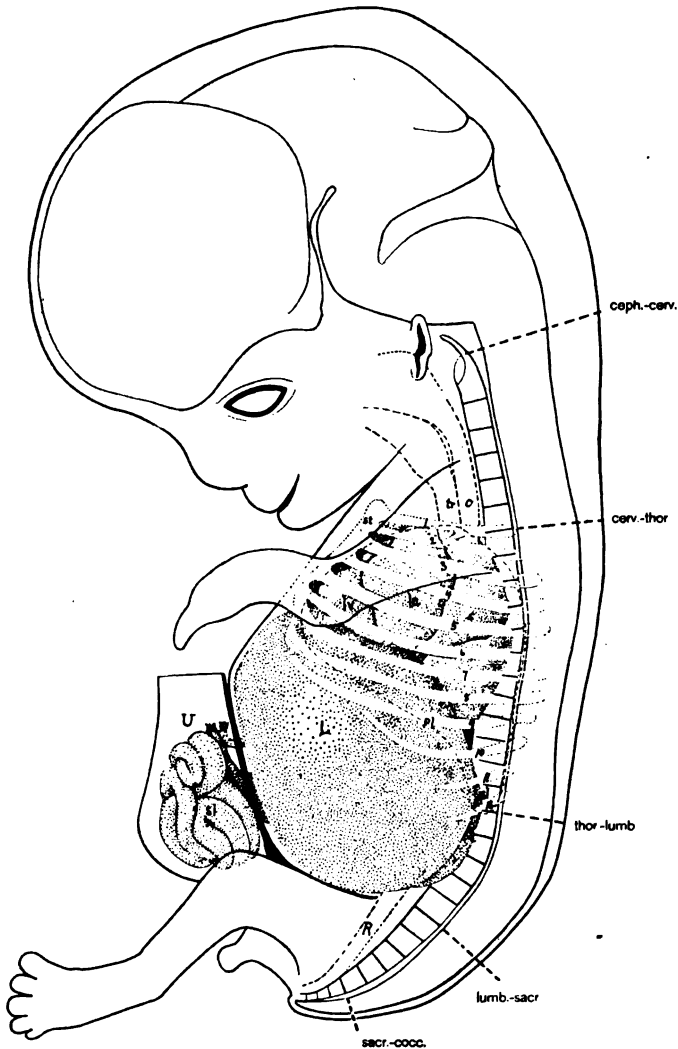


FIG. 3.—Graphic reconstruction of a 31 mm. human embryo (No. 57) from the left side, showing the body outline, extremities, central nervous system, vertebral centra, ribs, sternum, viscera, etc. The parts corresponding to the wax model (Fig. 7) are indicated by stippling. The various regions of the vertebral column are indicated (ceph.-cerv., cerv.-thor., thor.-lumb., lumb.-sacr., sacr.-cocc.).

kl, left kidney; ls, li, superior and inferior lobes of left lung; L, liver; la, left auricle; lv, left ventricle; o, oesophagus; pl, pleural boundary; R, rectum; sl, left suprarenal; sl, small intestine; st, sternum; tr, trachea; U, umbilical cord; ua, umbilical artery; uv, umbilical vein; 1 to 12, 1st to 12th ribs.

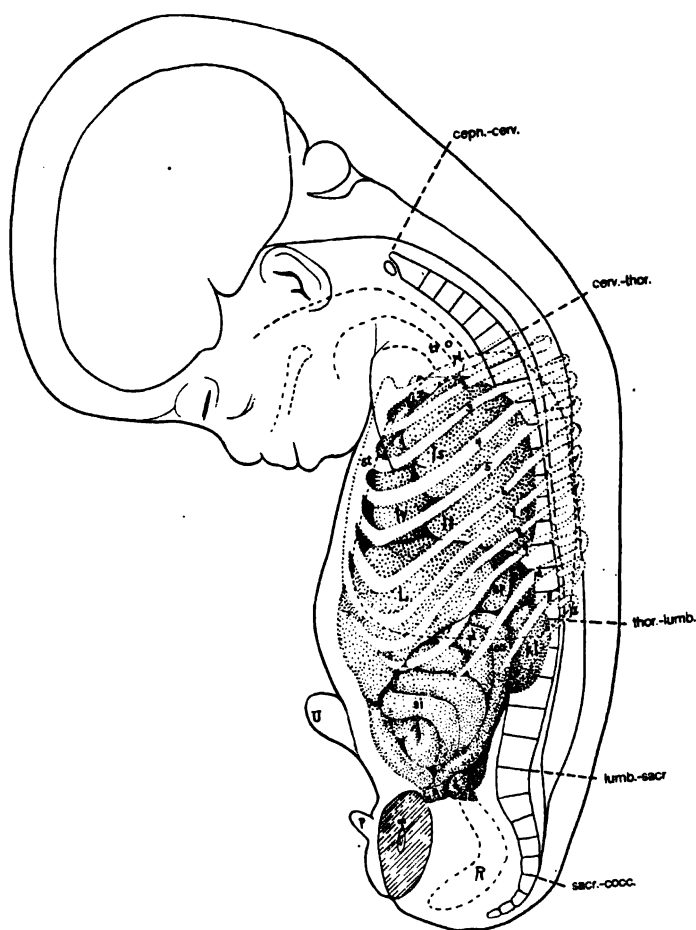


FIG. 4.—Graphic reconstruction of a 65 mm. human embryo (No. 55) from the left side, showing the body outline, extremities (cut off short), central nervous system, vertebral centra, ribs, sternum, viscera, etc. The parts corresponding to the wax model (Fig. 8) are indicated by stippling. The various regions of the vertebral column are indicated (ceph.-cerv., cerv.-thor., thor.-lumb., lumb. sacr., sacr.-cocc.).

co. colon; kl. left kidney; ls. li. superior and inferior lobes of left lung; L., liver; lv. left ventricle; o. oesophagus; p. penis; pl. pleural boundary; R. rectum; si. small intestine; sl. left suprarenal; sp. spleen; st. sternum; T. lower extremity, cut off just below the hip joint; t. testis; th. thymus; tr. trachea; U. umbilical cord; 1-12, 1st to 12th ribs.

FIGS. 5 to 8.—From photographs of wax models reconstructed by Born's method from human embryos, showing the thoracic and abdominal viscera, with projections of the ribs, viewed from the left side.

(For Figs. 5 to 8.) A, ascending aorta; a, descending aorta; a3, a4, 3d and 4th aortic arches; ac, anterior cardinal (jugular) vein; bw, body wall; c, anlage of cecum and appendix; ca, left common carotid artery; co, beginning of colon; da, ductus arteriosus; dC, ductus Cuvieri; hl, hind limb; ia, innominate artery; ic, ileo-cecal junction; kl, left kidney; L, liver; l, left lung; ls, ll, superior and inferior lobes of left lung; la, left auricle; lv, left ventricle; o, oesophagus; pc, posterior cardinal vein; ph, pharynx; R, rectum; r2-r12, projections of 2d to 12th ribs; ra, right auricle; rv, right ventricle; s, stomach; sa, left subclavian artery; sl, small intestine; sl, left suprarenal; sp, spleen; t, testis; th, thymus, tl, tm, lateral and median thyroid anlages; tr, trachea; ua, uv, umbilical artery and vein; w, Wolffian body; x, window in great omentum; ys, attachment of yolk-stalk to intestinal loop.

FIG. 5.—From an embryo of 11 mm. (No. 60), showing also the lower extremity, and the lower portion of the body wall.

FIG. 6.—From an embryo of 17 mm. (No. 58).

FIG. 7.—From an embryo of 31 mm. (No. 57).

FIG. 8.—From an embryo of 65 mm. (No. 55).

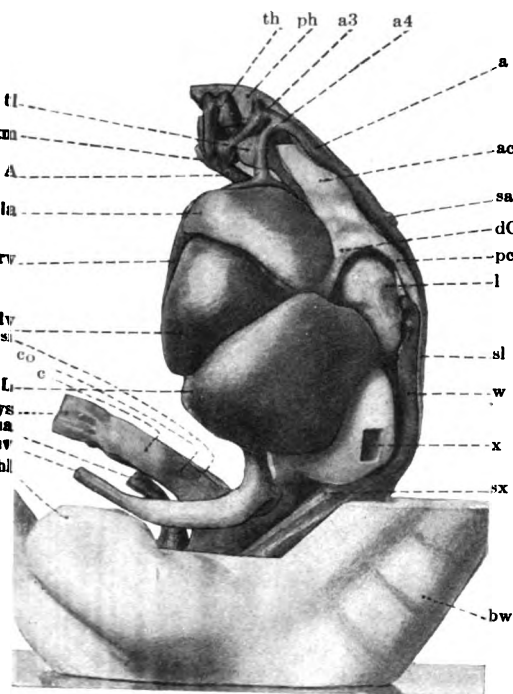


FIG. 5.

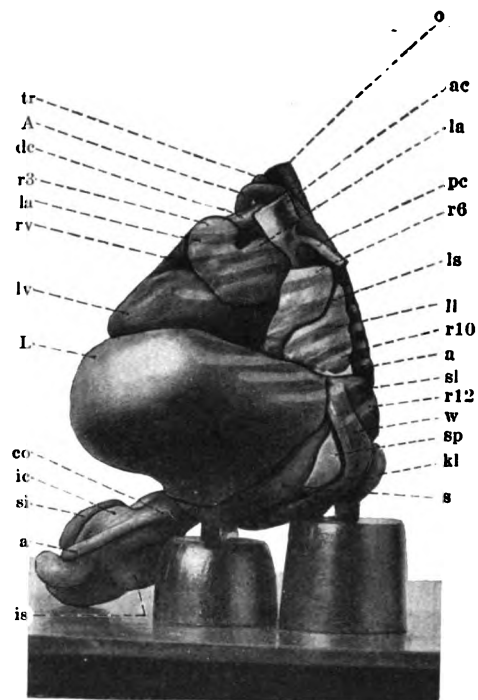


FIG. 6.

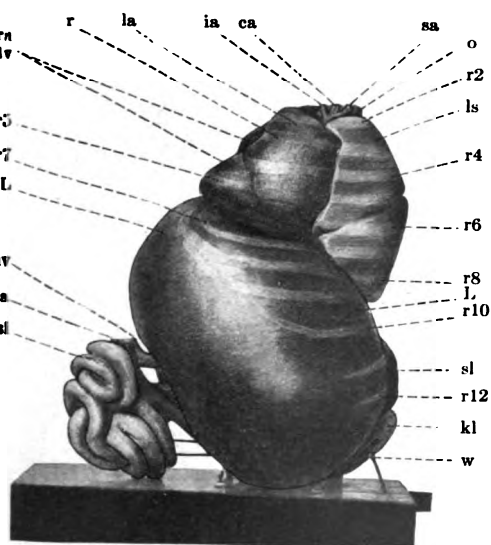


FIG. 7.

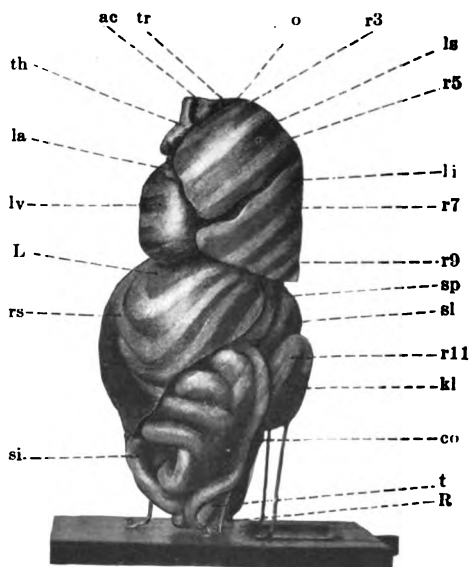


FIG. 8.

FIGS. 9 TO 12.—From photographs of wax models reconstructed by Born's method from human embryos, showing the thoracic and abdominal viscera with projections of the ribs, viewed from the right side.

(For Figs. 9 to 12.) A, ascending aorta (or arch); a, descending aorta; ac, anterior cardinal (jugular) vein; al, allantois; a2, a3, a4, 2d, 3d, and 4th aortic arches; c, anlage of cecum and appendix; cl, cloaca; co, beginning of colon; du, duodenum; gb, gall bladder; kr, right kidney; l, lung; ls, lm, ll, superior, middle and inferior lobes of the right lung; L, liver; n, notochord; o, oesophagus; po, posterior cardinal vein; ph, pharynx; r2-r12, projections of 2d to 12th ribs; ra, right auricle; rv, right ventricle; sa, subclavian artery; sc, spinal cord; sl, small intestine; sp, spleen; sr, right suprarenal gland; th, thymus; tl, tm, lateral and medium thyroid anlages; tr, trachea; u, ureter; ua, umbilical artery; uv, umbilical vein; vv, vitelline vein; w, Wolffian body; ys, attachment of yolk-stalk to intestinal loop.

FIG. 9.—From an embryo of 11 mm. (No. 60). In the lower part of the model, the body wall is represented as having been dissected away nearly to the mid-sagittal plane, so as to show a portion of the spinal cord, notochord, aorta, pelvic viscera, etc.

FIG. 10.—From an embryo of 17 mm. (No. 58).

FIG. 11.—From an embryo of 31 mm. (No. 57).

FIG. 12.—From an embryo of 65 mm. (No. 55).

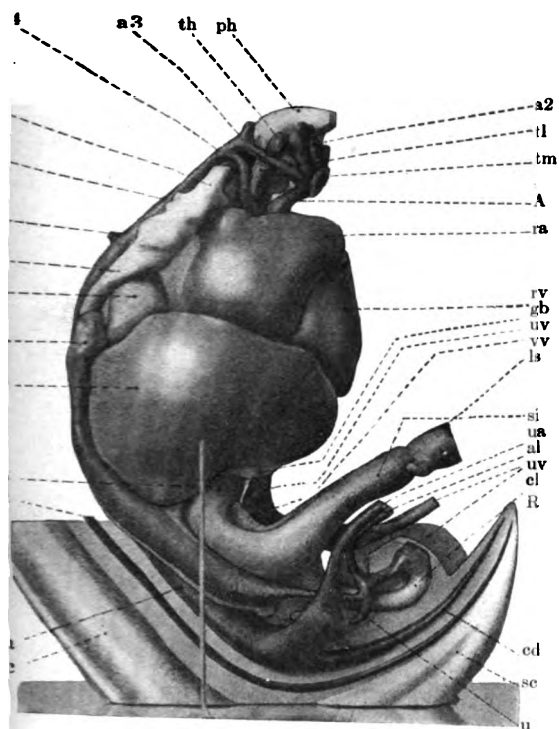


FIG. 9.

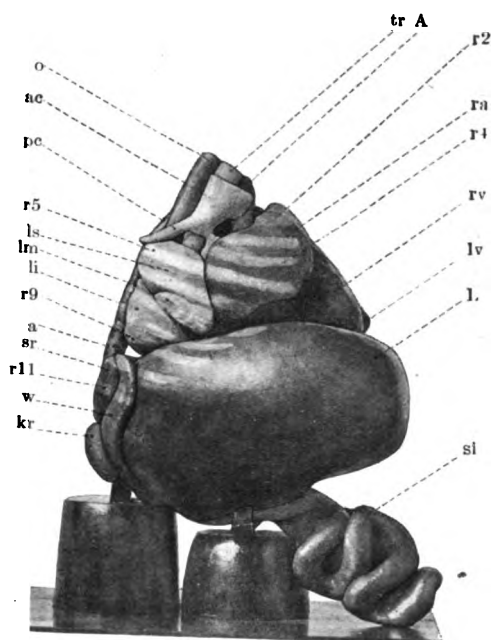


FIG. 10.

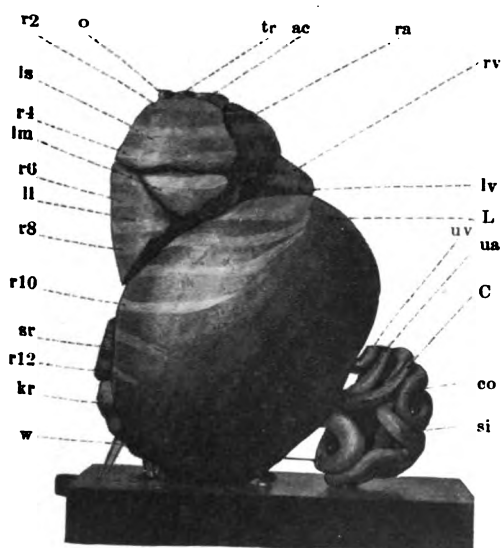


FIG. 11.

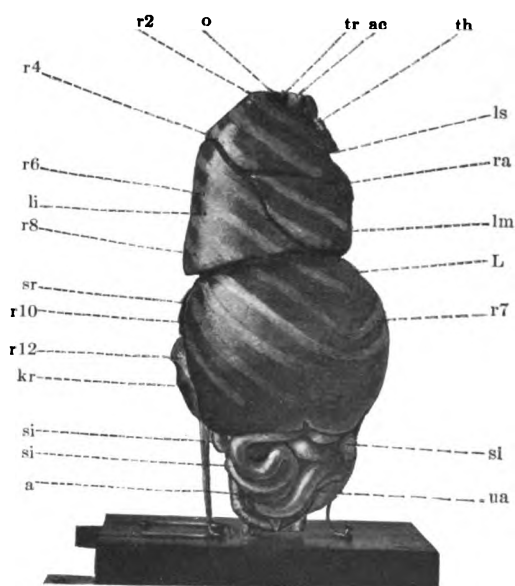


FIG. 12.

FIGS. 13 to 16.—From photographs of wax models reconstructed by Born's method from human embryos, showing the thoracic and abdominal viscera, with projections of the sternum and ribs, anterior view.

(For Figs. 13 to 16.) A, ascending aorta; ac, anterior cardinal (jugular) vein; al, allantois; a2, 2d aortic arch; bl, bladder; c, anlage of cecum and appendix; ca, left common carotid artery; co, colon; da, ductus arteriosus; gb, gall bladder; hl, lower extremity; ia, innominate artery; ic, ileo-cecal junction; L, liver; ls, lm, li, superior, middle and inferior lobes of the lung; la, left auricle; lv, left ventricle; lx, larynx; o, oesophagus; ph, pharynx; r2-r8, projections of 2d to 8th ribs, with corresponding costal cartilages joining the sternum; ra, right auricle; rv, right ventricle; sa, left subclavian artery; sc, spinal cord; si, small intestine; th, thymus anlage; tl, tm, lateral and median thyroid anlages; tr, trachea; ua, umbilical artery; uv, umbilical vein; va, vitelline artery (with accompanying vein).

FIG. 13.—From an embryo of 11 mm. (No. 60). Lower extremity and a portion of the lower body wall shown on the left side of the model.

FIG. 14.—From an embryo of 17 mm. (No. 58).

FIG. 15.—From an embryo of 31 mm. (No. 57).

FIG. 16.—From an embryo of 65 mm. (No. 55).

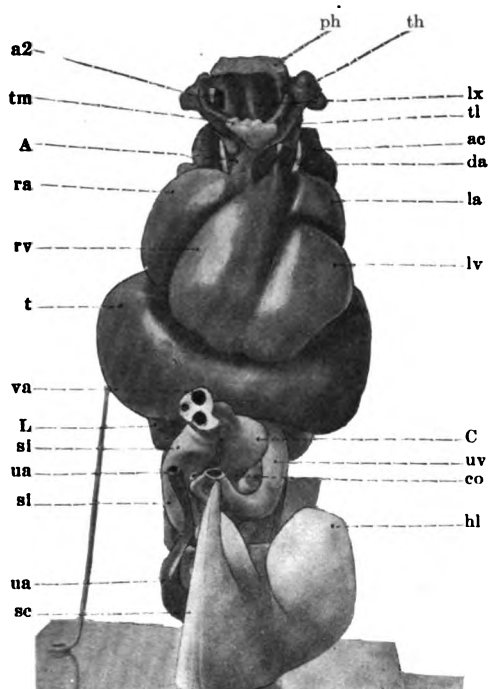


FIG. 13.

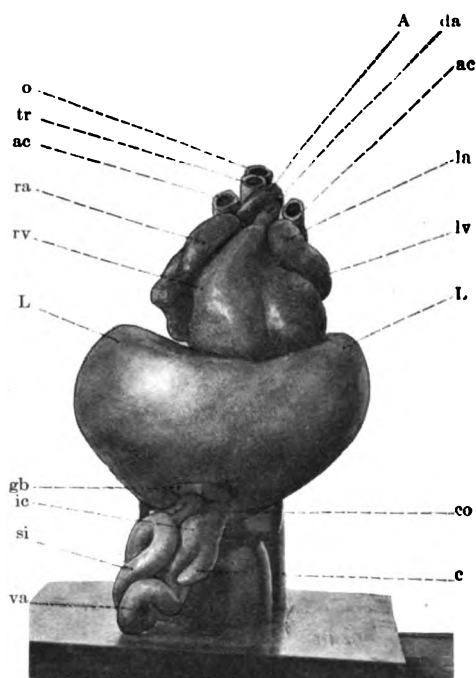


FIG. 14.

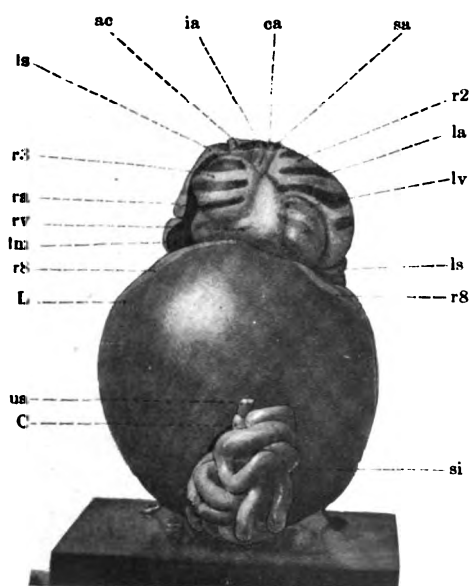


FIG. 15.

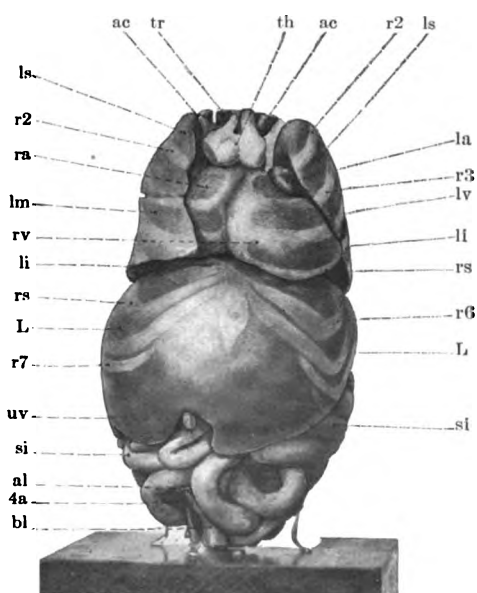


FIG. 16.

FIGS. 17 to 20.—From photographs of wax models reconstructed by Born's method from human embryos, showing the thoracic and abdominal viscera, with projections of the ribs and intervertebral disks, posterior view.

(For Figs. 17 to 20.) A, arch of aorta; a, descending aorta; ac, anterior cardinal (jugular) vein; ba, bifurcation of aorta; bw, body wall; co, descending colon; dc6-7, level of disk between 6th and 7th cervical vertebræ; dt3-4, disk between 3d and 4th thoracic vertebræ; dtl, disk between 12th thoracic and 1st lumbar; dl3-4, disk between 3d and 4th lumbar; du, duodenum; hl, lower extremity; hp, head of pancreas; kr, kl, right and left kidneys; L, liver; l, lung. ls, lm, ll, superior, middle and inferior lobes of lung; la, left auricle; o, œsophagus; pb, body of pancreas; pc, posterior cardinal vein; pco, pelvic colon; ph, pharynx; r2-r12, projections of 2d to 12th ribs; ra, right auricle; sa, subclavian artery; sc, spinal cord; si, small intestine; sl, sr, left and right suprarenals; sp, spleen; t, testis; th, thymus anlage; tr, trachea; u, ureter; vc, vena cava inferior; w, Wolffian body; x, window in great omentum.

FIG. 17.—From an embryo of 11 mm. (No. 60). Lower extremity and a portion of the lower body wall shown on the left side of the model.

FIG. 18.—From an embryo of 17 mm. (No. 58).

FIG. 19.—From an embryo of 31 mm. (No. 57).

FIG. 20.—From an embryo of 65 mm. (No. 55).

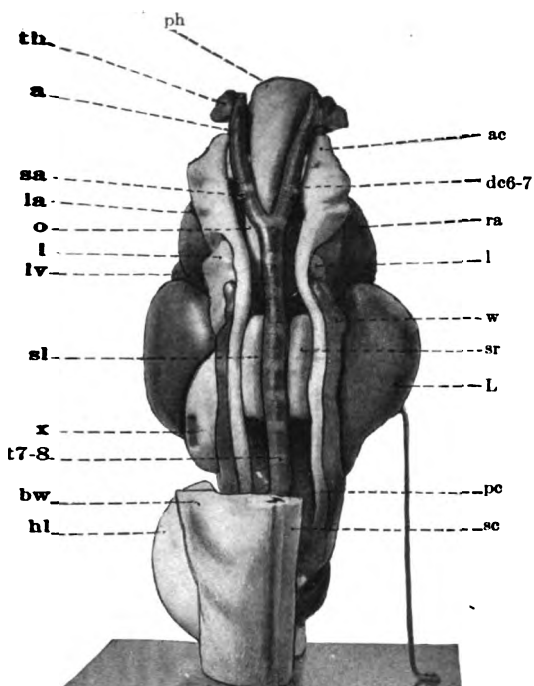


FIG. 17.

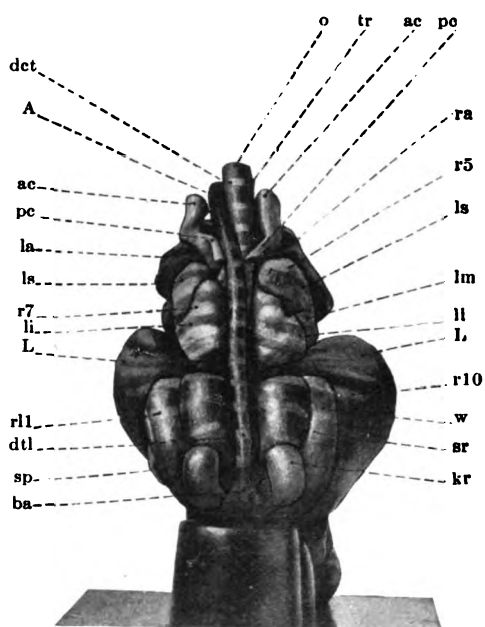


FIG. 18.

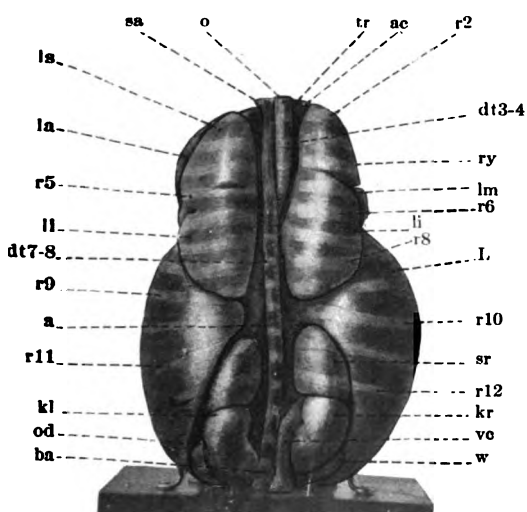


FIG. 19.

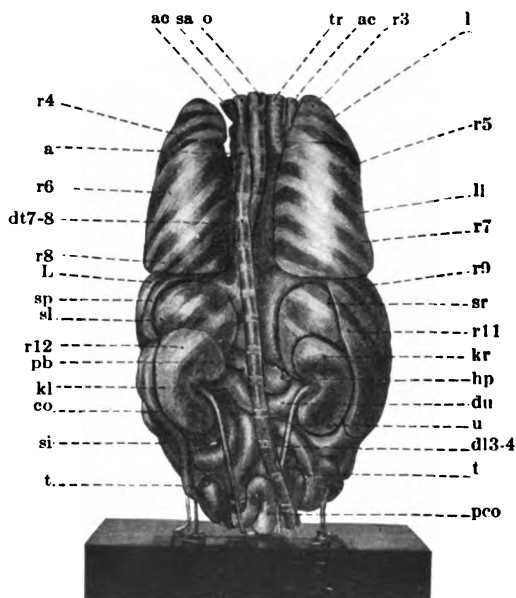


FIG. 20.

FIGS. 21 to 23.—Posterior view of the models as shown in Figs. 18 to 20, excepting that the kidneys, suprarenal glands, Wolffian bodies and sex glands have been removed.

(For Figs. 21 to 23, in addition to the explanations given for Figs. 18 to 20.) cr, cardia; dj, duodeno-jejunal flexure; dls, disk between last lumbar and first sacral vertebræ; gc, groove for inferior vena cava; gk, groove for kidney; go, groove for ovary; gs, groove for suprarenal gland; lc, caudate lobe of liver; s, stomach; tp, tail of pancreas.

FIG. 21.—From an embryo of 17 mm. (No. 58).

FIG. 22.—From an embryo of 31 mm. (No. 57).

FIG. 23.—From an embryo of 65 mm. (No. 55).

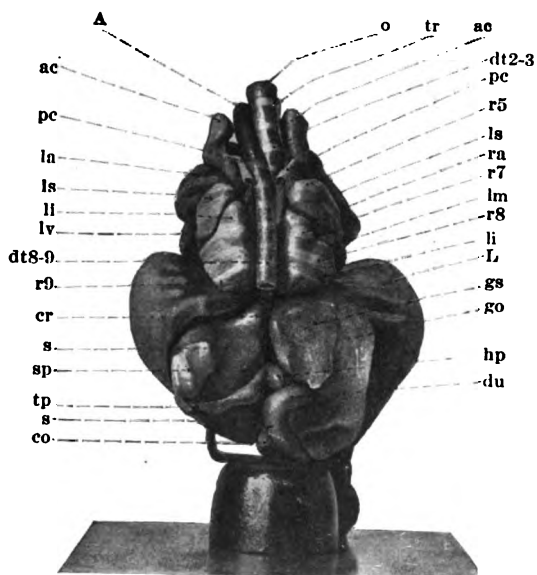


FIG. 21.

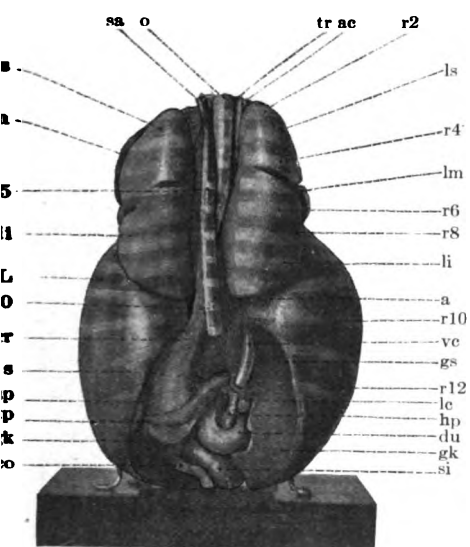


FIG. 22.

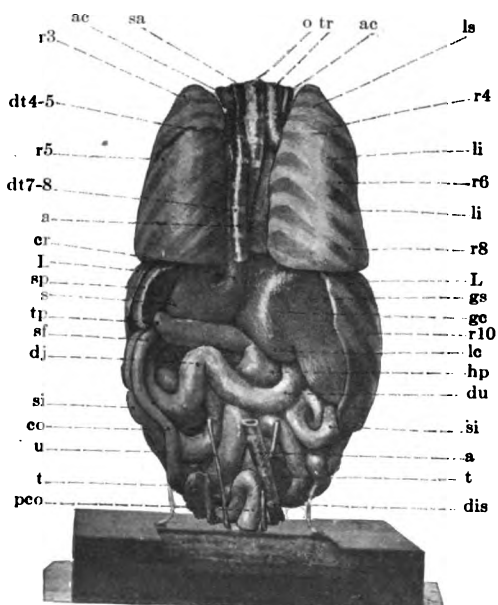


FIG. 23.

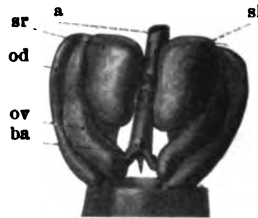


FIG. 21a.

FIG. 21a.—Anterior view of detached model showing the kidneys, suprarenal glands and sex glands of the 17 mm. embryo. A posterior view of this model is shown in Fig. 18, but it has been detached in Fig. 21. a, aorta, showing origins of the coeliac, superior and inferior mesenteric branches; ba, bifurcation of the aorta, with beginning of the caudal (middle sacral) artery; ov, ovary; od, oviduct; sr, sl, right and left suprarenal glands, below which a small portion of the kidneys is visible.

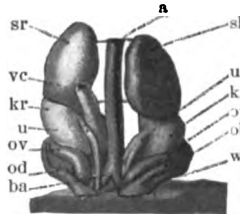


FIG. 22a.

FIG. 22a.—Anterior view of detached model showing the suprarenal glands, kidneys, etc., of the 31 mm. embryo. A posterior view of this model is shown in Fig. 19, but it has been detached in Fig. 22. a, aorta; ba, bifurcation of aorta; kr, kl, kidneys; ov, ovary; od, oviduct; sr, sl, suprarenals; u, ureter; vc, vena cava inferior; w, Wolffian bodies.

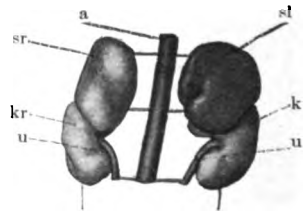


FIG. 23a.

FIG. 23a.—Anterior view of detached model showing the suprarenal glands and kidneys of the 65 mm. embryo. A posterior view of this model is shown in Fig. 20, but it has been detached in Fig. 23. a, aorta; kr, kl, kidneys; sr, sl, suprarenals; u, ureter.

A STUDY OF THE PARATHYROID GLANDS IN MAN.

BY

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New York City.*

The physiologic necessity of leaving the parathyroid glands uninjured in operations upon the thyroid region is now well known. It has also been demonstrated that the administration of beeves' parathyroids will to some extent relieve the postmortem tetany in man which follows the removal of the parathyroid glands (Halsted).

The number of parathyroid glands typically present has been quite generally stated as four, two posterior superior and two anterior inferior. Yet frequently at autopsy the typical four parathyroid glands are not to be found even after most careful dissection. The number which can actually be recovered varies from none to as many as six (Erdheim). This extreme variation has been ascribed to such causes as irregular number of glands in the individual, irregularities in their position, the presence of a varying number of accessory parathyroid glands, and even to the possibility of postmortem destruction of the small parathyroid glands by autolysis.

The reports of surgeons would lead one to believe that during operations upon the thyroid, the parathyroids are recognized with relative ease and can be preserved together with their blood supply. Parathyroid serums and extracts have been prepared, presumably without microscopical confirmation of the tissue used in their manufacture. If a relatively small percentage of the tissue so used is actually parathyroid, the serum or extract will certainly contain a considerable admixture of the products of such other tissues as thyroid gland, lymphatic nodes and thymus; and experimental results based upon the specificity of such extracts must be interpreted in the light of this possible source of error.

In view of these considerations further anatomical studies of the parathyroid glands for the purpose of providing a more firm and accurate foundation upon which to build and interpret physiologic experiment and surgical procedure appear most desirable.

RECOGNITION OF PARATHYROID GLANDS.

The following notes, based upon autopsies of bodies in the best state of preservation, one excepted, indicate that only 41 per cent of probable parathyroid glands, as identified by gross inspection, actually contain parathyroid tissue when examined microscopically. This percentage does not widely differ from the results obtained by Rogers and Ferguson, who found 61 parathyroids out of 189 pieces examined, or in 32.4 per cent (all suspicious looking pieces being included). In certain cases the gross appearance is undoubtedly misleading, tissue not resembling the classical type proving to be parathyroid after microscopic examination. Less frequently tissue presenting the typical macroscopic features of parathyroid is found to be lymphoid or other tissue.

The results of the gross dissection of the several autopsies are given somewhat in detail because of their relation to the question of the percentage of cases in which one may hope that the glands may be positively recognized by the unaided eye, without microscopical study.

Autopsy I.¹ W. M., aged 35; five hours post-mortem. Mental diagnosis, senile delirium. Cause of death, acute enteritis. In this case three pieces of tissue, none bearing the characteristic stamp of the parathyroid, were dissected, two from the posterior-superior aspect of the lateral lobes of the thyroid and one from the anterior surface of the esophagus on the right side. All proved to be adenoid tissue.

The failure to obtain the parathyroids in this case may have been due (1) to rapid autolysis, (2) neglect to secure all tissues bearing the slightest resemblance to a parathyroid, (3) the possibility of the

¹The material used was obtained in 1907 through the kindness of the Hudson River State Hospital, Poughkeepsie, N. Y. My thanks are due this institution for the opportunity offered.

glands being situated beyond the limited field of dissection, or (4) the remote possibility of an unobserved location within the thyroid gland.

Autopsy II. S. R., aged 55; twelve hours post-mortem. Mental diagnosis, epileptic insanity. Cause of death, appendicitis with perforation. In this case the tissue had undergone extensive post-mortem change. Only one very small piece of tissue resembling parathyroid was found, being located at the superior pole of the left thyroid lobe, posteriorly. Microscopical examination proved this to be thyroid tissue.

Autopsy III. D. W., aged 22; seven hours post-mortem. Mental diagnosis, epilepsy with insanity. Cause of death, septicæmia following carbuncle.

The two left parathyroids were readily recognized by (1) the yellowish brown color, (2) smooth, finely textured surface, (3) lack of the firmness which characterizes the thyroid and other tissue so often confused. Both left parathyroids were found on the posterior surface, the lower one, however, being anterior to the main branch of the thyroid artery. Six other suspicious looking pieces of glandular tissue were removed from the loose areolar tissue bordering on the right lobe and along the esophagus. One of these proved to be the right anterior parathyroid. The fourth parathyroid, if present, must have been outside the field of dissection.

Autopsy IV. L. W., aged 40; seven hours post-mortem. Mental diagnosis, general paresis. Cause of death, general paresis.

The two anterior parathyroids were recognized by the characteristics above mentioned. Both were located between the branches of the inferior thyroid artery and upon the lateral lobes of the thyroid gland. Two other pieces of tissue were examined, one from the superior pole of the left lobe of the thyroid and another from the anterior surface of the esophagus, on the right side. The former proved to be thyroid and the latter adenoid tissue.

Autopsy V. M. B., aged 36; two hours post-mortem. Mental diagnosis, imbecility with insanity. Cause of death, pulmonary tuberculosis.

The two anterior inferior parathyroids were immediately recog-

nized. The posterior glands were not found in the usual location, and having in mind the possibility of an internal position, large wedge-shaped areas of thyroid were excised from the upper posterior surface of the lobes. These were sectioned throughout, but no parathyroids were found. A search was made along the wall of the pharynx and esophagus, but no tissue resembling parathyroid was found.

Autopsy VI. A. P., aged 70; eight hours post-mortem. Mental diagnosis, melancholia simplex. Cause of death, carcinoma with multiple metastases.

The two posterior superior parathyroids were found, the right one being in direct relation to the esophagus. Just anterior to the main artery of the right thyroid lobe, a gland was removed, bearing all the characteristics of the parathyroid. On microscopical examination this proved to be adenoid tissue. This was the only instance in the ten autopsies in which a piece of tissue having the typical color, consistency and location proved not to be parathyroid. To secure the left inferior parathyroid a wedge-shaped area was excised from the thyroid and a small gland removed from the areolar tissue just external to the left thyroid lobe. No parathyroid tissue was found in the thyroid and the small gland proved to be a bit of accessory thyroid tissue.

Autopsy VII. A. J. B., aged 55, eight hours post-mortem. Mental diagnosis, imbecility with insanity. Cause of death, lobar pneumonia.

The field of dissection was limited and but three blocks of tissue were obtained. At the extreme inferior pole of the left thyroid lobe, beneath the branches of the inferior thyroid artery, a parathyroid was found, the gland extending over upon the anterior surface of the thyroid. Two other pieces of tissue were removed, one from the esophagus at the level of the superior border of the cricoid cartilage and the other from the surface of the larynx on the left at the same level. Neither had all the essential attributes of parathyroid and both proved to be thyroid tissue.

Autopsy VIII. P. F., aged 40; twelve hours post-mortem. Mental diagnosis, epileptic insanity. Cause of death, asphyxia following convulsion.

The tissue was badly congested and no parathyroids were found in the customary locations. Four wedge-shaped pieces of tissue were excised from the thyroid at the most likely points, but no parathyroids were found.

Autopsy IX. E. K., aged 32; twelve hours post-mortem. Mental diagnosis, alcoholic psychosis. Cause of death, chronic interstitial nephritis.

All four parathyroids were readily recognized and secured. The inferior parathyroids were both at the extreme lower poles of the thyroid. The superior parathyroids were situated rather laterally than posteriorly. But four blocks of tissue were obtained in this case, the glands being characteristic. No search for accessory parathyroids was made.

Autopsy X. W. P. II., aged 48; twenty hours post-mortem. Mental diagnosis, maniacal depression. Cause of death, cardiac valvular disease with nephritis.

Three parathyroids were obtained in this case, all located upon the posterior surfaces of the thyroid lobes, two on the left, the other on the right. Of the two left parathyroids, one was found immediately beneath the superior pole, lying in the groove between the thyroid and esophagus, the other, three centimetres below in the same vertical line. The third was found in the same relative position on the posterior surface of the right lobe. No other tissue was searched for parathyroid, as it was badly congested.

With one or two exceptions all of the glands were fixed in Van Gehuchten's fluid. They were then hardened in graded alcohol, embedded in paraffin, sectioned and stained with hematein and eosin.

The following conclusions are based upon the dissection and microscopical study of the 17 parathyroids obtained:

1. *Size.* The size varied from 2 x 4 x 6 mm. to 4 x 6 x 10 mm. The average size was about 3 x 5 x 8 mm.
2. *Color.* Typical yellowish brown 13 glands
 Deep red brown (congestion) 3 glands
 Light yellow 1 gland

3. <i>Consistency.</i>	Typical, flaccid	12 glands
	Tense, hard	3 glands
	Medium	2 glands

4. *Number and location.*

Number of autopsies in which 4 glands were obtained.....	1
Number of autopsies in which 3 glands were obtained.....	2
Number of autopsies in which 2 glands were obtained.....	3
Number of autopsies in which 1 gland was obtained.....	1
Number of autopsies in which no glands were obtained....	3

Total number of glands obtained17

Number of <i>superior</i> glands obtained	6
Number of <i>inferior</i> glands obtained	11
Number of glands irregularly situated	7

Superior: found on esophagus	1
Inferior: found on esophagus	1
Inferior: found at extreme inferior pole	3
Inferior: found on posterior surface	2

D. A. Welsh (Jour. Anat. and Physiol., 1898, XXXII, page 383) says "the posterior-superior parathyroid of each side is much more constant in its position, and much more easily found than the anterior inferior glandule." Contrary to the experience of Welsh, the inferior parathyroids in the above series seem the more easily located, in all except two cases being found anterior to the inferior thyroid artery, and in all except four cases being located at the first branch of this artery on the thyroid lobe.

5. *Recognition of the glands.* In many cases the parathyroids can be definitely recognized by gross inspection if the tissue is fresh and not badly congested or pigmented or otherwise altered. In only one instance in ten did a gland with a smooth surface, of yellowish-brown color and flaccid consistency, fail microscopical confirmation, while seven atypical pieces of tissue proved to be parathyroids. In none of the ten autopsies were more than two parathyroids found in

their typical location, but in autopsy IX, in which four parathyroids were found, the superior were typically located while the two inferior were atypical only in that they were displaced toward the inferior pole of the thyroid and were inferior to the thyroid branch of the inferior thyroid artery. Although glands of typical parathyroid appearance rarely failed of confirmation, the converse was more frequently true, that in certain instances glands of variable color and consistency proved to be parathyroid.

Tissue resembling parathyroids on dissection would seem to be divisible into three groups: (1) in which the location, form, size and color appear wholly characteristic to the unaided eye—such tissue on sectioning rarely proves to be other than parathyroid; (2) in which location, form, size and color approximate the typical—a considerable portion of these prove not to be parathyroid on microscopical section; (3) in which the location, form, size or color are wholly atypical—such occasionally prove to be parathyroids.

The obvious surgical importance of the above seems to be two-fold, viz., the surgeon during thyroidectomy can be reasonably certain of his identification of certain of the parathyroid bodies when they can be found, but to insure the preservation of these glands they must leave intact much, if not all, of the glandular tissue found in the immediate vicinity of the thyroid gland, bearing in mind, also, that the number of parathyroids constantly present in each individual has not been demonstrated to be as many as the typical number, four.

To those studying the parathyroids it soon becomes evident that if four glands are to be obtained in each case very extensive search is necessary. Only very rarely can four glands be immediately and definitely recognized. In cases in which, for example, but three glands are identified one is obliged to preserve all possible tissue from the hyoid bone to the aortic arch before excluding the presence of a fourth gland. If this search fails to locate the missing gland a complete sectioning of the entire thyroid may produce it, owing to its occasional location within the capsule of the thyroid gland.

ANATOMY AND HISTOLOGY.

In man the parathyroids may be as many as four in number,

occasionally five or six (Erdheim). They vary in size from that of a grain of rice, or even smaller, to that of a small white bean. Their color is quite characteristic, a peculiar yellowish brown, in contrast to the deep red of the thyroid. Their surface is smooth and conveys the idea of a tissue of finer elements than that of the thyroid or other tissue, for example, lymphatic nodes, thymus rests, with which parathyroids may be confused. In many instances the parathyroid is situated in direct relation to the thyroid gland, less often in relation to the esophagus or trachea. The glandules have been found superiorly as far as the hyoid bone and inferiorly as far as the bifurcation of the trachea or upon the arch of the aorta in relation to the thymus (Welsh). The last named position is stated by Welsh as being the most common in the cow. The parathyroid glands most readily located are the ones known as the anterior inferior parathyroids, usually situated at the inferior poles of the lateral thyroid lobes, although there is much individual variation in their position (Rogers and Ferguson). Welsh however states that in his series of cases the superior were the more easily recognized, whereas in the present series of autopsies the inferior parathyroids were much the more easily recognized and more constantly present. The inferior thyroid artery forms a guide to the two inferior glands which often rest in the bifurcation of the artery upon the anterior inferior surface of the thyroid on either side. The two remaining parathyroid glands are most frequently found posteriorly at the superior pole of the thyroid. Very often one or both of the superior parathyroids is found upon the esophagus. In rare cases a human parathyroid may be embedded within the thyroid gland, and this location is quite the usual one for the inferior parathyroid of the dog, horse and goat (Rogers and Ferguson).

The parathyroid is described as an epithelial structure resembling the glandular portion of the hypophysis cerebri. The epithelial cells are of two varieties: (1) so-called *principal cells*, which have a distinct limiting membrane or wall and are outlined by the supporting stroma of reticulum, thus assuming a polygonal, often pentagonal shape; they have a clear cytoplasm, and a centrally situated and often vesicular nucleus; the principal cells predominate: (2) *oxyphile* or

acidophile cells, somewhat larger than the principal cells, and have distinct outlines, a finely granular and acidophile cytoplasm, and a centrally situated nucleus which is small in proportion to the size of the cell and often highly chromatic. The acidophile cells are irregularly placed among the masses of principal cells, either singly or in small groups. These groups are often situated immediately beneath the capsule in wedge-shaped areas, or in relation to blood-vessels.

The stroma includes a capsule, always present, consisting of delicate white fibrous connective tissue. From the inner surface of the capsule fine trabeculae are given off, which in some cases appear to divide the gland into lobules. In many glands there is a distinct hilum by means of which the arteries of supply—branches of the inferior thyroid—enter the glandular substance, supported by the trabeculae.

There is no duct through which a secretion may leave the gland. The tubular cysts found in the parathyroids of the goat, horse, and occasionally in other mammals (Kohn, Edmunds, Rogers and Ferguson) can not be considered as in any sense ducts, for they do not receive the secretion from the parathyroid parenchyma nor do they open upon any free surface. They are closed cysts and more nearly than anything else they simulate the branchial cysts which are frequently found in the connective tissue about the trachea, and which are of a congenital type, probably due to the embryonal dislocation of primordial epithelial cells from the branchial clefts. The embryology of the parathyroids would suggest a similar origin for the ciliated epithelium lining the occasional colloid-containing cysts within their substance.

No peculiar histology of the larger parathyroid blood-vessels presents itself, the coats being properly proportioned. The arterioles empty into an extensive sinusoidal system of capillary vessels which are then collected by the radicals of the venous system. The arrangement of the epithelial cells seems dependent upon the blood-vessels, the intimate contact of parenchymal cells and vascular epithelium suggesting the escape of secretion into the sinusoidal vessels. It is believed that the arrangement of cells varies somewhat with the age

of the individual. In young subjects the columnar arrangement of the epithelial cells seems to predominate (Ferguson). Later in life the cells show either a diffuse arrangement or assume something of an alveolar grouping. In rare instances within the parenchyma there are alveoli containing a colloid material, but in these cases the cells lining the alveoli are low columnar or cuboidal cells resembling the true glandular cells of the thyroid and bear no obvious resemblance to the parenchymal cells of the parathyroid. These alveoli would seem to form no essential part of the parathyroid structure.

Most parathyroid glands contain fat, either in discrete cells or in groups. The presence of fat, however, very probably does not account for the somewhat characteristic yellow tint of the yellowish brown parathyroid glands, which is apparently an intrinsic property of the parenchymal cells, for many of the glands of my series which possessed a most characteristic yellowish tint proved on sectioning to contain very few or no fat cells. The remaining brownish tint appears to be due to the extreme vascularity of the gland.

The following is a summary of the histological findings in the seventeen parathyroid glands removed from the above described autopsies.

Capsule.—The capsule was invariably present, varying greatly in thickness and structure. In most cases the capsule was found to consist of white fibrous tissue apparently containing some smooth muscle. From the inner surface, septa composed of a delicate reticulum of fibrous tissue were found to penetrate between the parenchymal cells. These septa support the blood-vessels.

Hilum.—A more or less distinct hilum was found in each gland, the arteries entering and veins leaving at this point.

Reticular Tissue.—After tryptic digestion for twenty-four hours of sections of the parathyroid gland—removing the white fibrous connective tissue, elastic tissue, muscle and epithelial cells—a delicate reticulum remains. Hence, it would seem that this is true reticular tissue; it appears to form the ultimate framework of the parathyroid. The distribution of the reticular tissue corresponds to the outlines of the capsule, septa and parenchymal cells, principal and oxyphile.

Blood-vessels.—The parathyroids were in all cases found to be

highly vascular. The histological study of the arteries and veins revealed nothing indicating any possible structural relation of the vascular system to the glandular secretion, such as is found in the excessive development of the longitudinal muscle of the media of the adrenal veins (Ferguson). The capillary network pervading the gland is very delicate and seems to determine the grouping of the cells, the resulting arrangement of the cells presenting either a columnar or alveolar form. The columnar grouping was not observed, this arrangement being more frequent on younger subjects. In five instances an acinar grouping was indicated. In one of these the acini seemed very distinct, and a few of them contained colloid. In many glands there were broad vascular spaces lined by a single layer of endothelium—so-called sinusoids.

Principal Cells.—The limiting membrane of the cell was usually distinct. Each cell most commonly had a pentagonal outline; its cytoplasm was clear, often taking a faint bluish tinge in sections stained with hematein and eosin. The nucleus was centrally situated and often vesicular in character.

Acidophile Cells.—In size these were somewhat larger than the principal cells. The limiting membrane was fairly distinct and the cells had a polygonal outline. The cytoplasm was finely granular and strongly acidophile. The nucleus was centrally situated and often deeply chromatic; occasionally multiple. In twelve cases the acidophile cells were found dispersed uniformly among the principal cells without evident relation to capsule, septa or blood-vessels. In the remaining five cases some of the acidophile cells were found in distinct, often wedge-shaped areas beneath the capsule or in relation to septa or blood-vessels.

Fat.—In five glands no fat cells were found either in the capsule or among the epithelial cells. In four glands the fat cells were found in discrete arrangement only. In two glands fat occurred in large masses only, and in the remaining six the fat cells were found in both discrete and grouped arrangement.

Color.—The distinctive yellowish brown color of the parathyroid has been attributed to the presence of fat (Welsh). A review of the five glands in which I found no fat shows that the color in each

instance was a characteristic yellowish brown, and it must, therefore, be an inherent property of the parenchymal cells; possibly the color may be due to reflected light from the masses of principal cells, the clear cytoplasm of which, together with the extreme vascularity of the gland, may combine to produce the characteristic yellowish brown.

PATHOLOGY.

Nothing of importance from a pathological viewpoint was noted in any of the glands. In one case, in which there was extreme congestion of all the organs, some pigmentary deposit was found in the small areas of hemorrhage. No evidences of degeneration were found unless the presence of colloid containing follicles in two glands may be considered. No new growths were found, not even a metastasis in the case of general carcinoma.

In closing, I desire to express my thanks to Dr. J. S. Ferguson, Assistant Professor of Histology, at whose suggestion and under whose direction the present study was undertaken.

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ANOMALIES OF THE PULMONARY ARTERY IN NECTURUS.

BY

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The specimens of *Necturus maculosus* (Raf.) to be described in this paper are adult animals, which have been injected through the ventral aorta with red starch mass. The injections may be called good, since the main arterial vessels and their branches are well distended. None of the specimens show any evidence that the pulmonary circulation has been disturbed through injury or pathological condition.

In the first case the arteries are arranged as shown in Fig. 1. The right side of the animal is normal. Here the pulmonary artery arises from the combined portion of the second and third efferent aortic arches. On its way to the lung it sends small branches to the muscles of the pectoral region.¹ These are comparable with the large cutaneous branch of the pulmonary artery in the frog.² After sending out the pectoral branches, the pulmonary artery of *Necturus*, as described by Miller, "passes across the dorsal surface of the lung to gain its dorso-mesial side, along which it runs, gradually diminishing in size, to its tip."³ This normal condition is found on the right side.

The left lung of the *Necturus* shown in Fig. 1 receives its blood at its extreme distal end. The supply is from a large seventh intercostal trunk, which appears at the level of the twelfth vertebra, posterior of the celiac artery. This intercostal vessel divides at once on

¹These branches have been described by W. S. Miller in "The Vascular System of *Necturus maculatus*." Bull. Univ. Wisconsin, No. 33, pp. 213-214.

²Ecker, A. The Anatomy of the Frog. (Translated by G. Haslam.) 1889, p. 229, Fig. 149.

³Miller, William S. The Blood and Lymph Vessels of the Lung of *Necturus maculatus*. Amer. Journ. Anat., 1905, Vol. IV, p. 446.

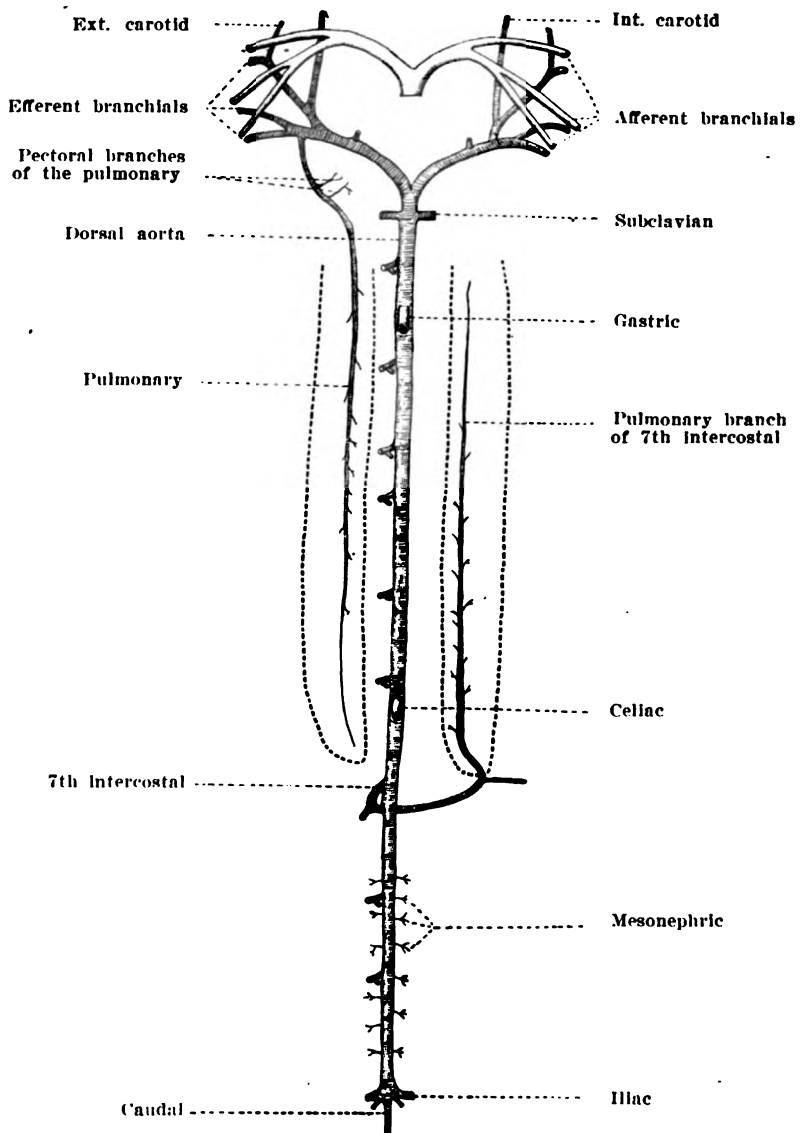


FIG. 1.—Ventral view of the arteries of an adult *Necturus*. Natural size. The right lung receives its blood from the 2d and 3d efferent branchial arteries, as is normal; the left lung is supplied by a branch of the seventh intercostal artery.

leaving the aorta and is so turned that both divisions are on the right side. The left branch, which is much larger, turns towards its own side dorsal to the aorta. It is entirely free from the musculature until after it has branched. The larger portion then enters the left lung near its tip and runs forward along its ventro-mesial side. The remainder of the vessel, reduced to less than one-third of its previous size, penetrates the musculature of the left side of the body about 5 mm. laterally from the tip of the lung.

This pulmonary vessel appears as the reverse of the normal artery, since it runs anteriorly from the tip toward the base of the lung. It gives off lateral branches alternately, and grows smaller and smaller until the starch mass can penetrate no farther. Beyond this point a fine line, due to the presence of clotted blood, indicates the continuance of the vessel for a short distance. The diminution and stopping of the injected vessel while on the lung, and the absence of any starch mass starting from the fully injected aortic arch, indicate that there is no vessel at all comparable with the normal proximal end of the pulmonary artery. It is quite possible, however, that it is represented by capillary connections.

This extraordinary anomaly may be readily explained through embryological development. It is generally believed that after the vascular system has become established in very young embryos, all subsequent vessels arise from it as offshoots. Where there is a connective tissue pathway, a branch from a neighboring vessel is likely to enter it and to anastomose with such other vessels as it encounters. If a favorable channel results, the small vessel becomes a main channel.⁴ A striking illustration of this mode of development has recently been supplied by Spalteholz.⁵ It has been known for some time that in certain reptiles a bridge of connective tissue extends from the tip of the heart across the pericardial cavity to the thoracic wall. Spalteholz has shown that a branch of the adjacent

⁴This conception of vascular development was advocated by F. T. Lewis at the meeting of American Anatomists in 1903, and by H. E. Evans at their last session, in 1908.

⁵Spalteholz, W. Zur vergleichenden Anatomie der Aa. coronariae cordis. *Verh. der. anat. Gesellschaft*, 1908, pp. 169-180.

internal mammary artery may enter this bridge and extend to the heart, thus becoming a coronary artery. The heart may receive its blood supply from its apex as well as from its base provided that the connective tissue pathway is present. In the lung of *Necturus* the mesentery is the connective tissue path, although a slender and apparently unfavorable one. In the specimen under discussion either a branch of the pulmonary artery passed out from the lung to anastomose with the intercostal artery, or a branch of the latter

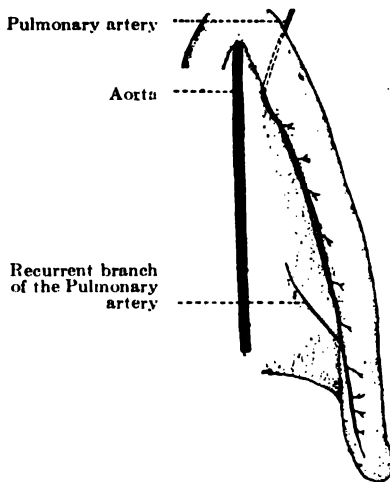


FIG. 2.

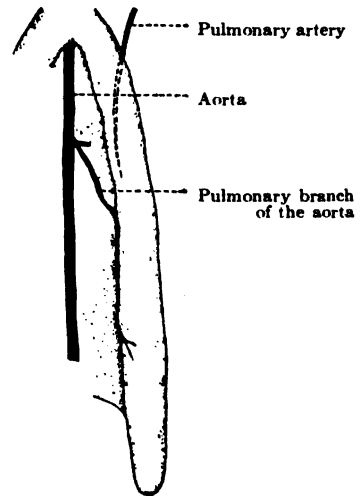


FIG. 3.

FIGS. 2 and 3.—Variations in the pulmonary arteries in the left lung of *Necturus*. 2/3 natural size.

entered the lung and joined the pulmonary branches. That both of these processes occur is suggested by the following variations.

Fig. 2 represents a left lung, 100 mm. in length, which is free from the mesentery along its distal 20 mm. At a point 9 mm. before the lung becomes free, at the level of the middle of the eleventh vertebra, a fairly large branch passes from the pulmonary artery toward the median line. It is enclosed in the mesentery. This branch tapers gradually without forking, and terminates without making demonstrable connections with other vessels. It clearly conveyed a stream of blood away from the lung. In the case shown

in Fig. 3, however, the dorsal aorta sends a branch to the left lung which supplies its distal two-thirds.⁶ Here the current of blood is toward the distal end of the lung instead of away from it as in Fig. 2.

All three of these variations may be explained on the basis of embryonic capillary connections between the dorsal aorta and the pulmonary artery. Although such connections have not yet been observed in *Necturus* embryos, they may be confidently predicted. They have already been found by Dr. Evans in chicks incubated from sixty to seventy hours. It will be remembered that in the human adult, branches of the bronchial artery, which comes from the aorta, have been said by several investigators to anastomose with the pulmonary artery in the lung. Miller and others are unable to find such connections.⁷ But Nicolas⁸ has stated that "it appears well established that the pulmonary arteries (of man) anastomose with the bronchial arteries not only through a capillary network, but also by branches which are quite large, and which may attain a diameter of 0.5 mm. or more." Detached portions or "accessory lobes" of the human lung are sometimes supplied entirely by a branch of the thoracic aorta, and are drained by veins emptying into the azygos system. Simpson⁹ described such a case in a child at birth, and found records of two others, occurring at three months and eighteen years respectively. In one case the artery to the accessory lobe left the aorta at the level of the seventh thoracic vertebra; in the other two it was at the level of the tenth vertebra. This is comparable with the arrangement in the abnormal *Necturus*.

Abnormal vessels entering the lung of the frog, near its apex, have been found by several observers. The veins have received more attention than the arteries. T. W. Shore has figured two cases, in

*The dissection and sketch of this specimen were made by Dr. F. T. Lewis when studying with me in the zoological laboratory in Cambridge. I am indebted to him for the memorandum concerning it.

⁶Miller, William S. The Arrangement of the Bronchial Blood vessels. (Preliminary Communication.) *Anat. Anz.*, 1906, Vol. 28, pp. 432-436.

⁸Nicolas, A. See Poirier's *Traité d'Anatomie Humaine*, Paris, 1895, Vol. IV, p. 528.

⁹Simpson, G. C. E. A case of accessory lobe of the right lung. *Journ. Anat. and Phys.*, 1908, Vol. 42, pp. 221-225.

one of which a branch of the renal portal vein, and in the other a branch of the hepatic portal vein entered the lung.¹⁰ E. Warren¹¹ had previously described and figured three similar cases, in one of which a branch of the renal portal vein joined a branch of the hepatic portal, and the resulting trunk entered the left lung near its apex. In this case it is recorded that a branch of the posterior mesenteric artery accompanied the vein into the lung, and the figure indicates that it anastomosed with a normal pulmonary artery. Warren states that "this arrangement of blood-vessels is strikingly similar to that seen in a teleostean fish, where an artery runs from the mesenteric artery into the rete mirabile of the air-bladder, and from there the blood is carried by a vein into the portal system." But he hesitated very properly before interpreting the anomaly in the frog as a reversion to a fish-like ancestor. G. P. Mudge¹² recorded still another case occurring in the frog. A branch of the celiac artery entered the right lung and two branches of the superior mesenteric artery entered the left lung. On both sides the arteries were accompanied by branches of the portal vein. Mudge states that in *Ophidia Hyrtl* found secondary pulmonary arteries arising from the aorta and the arteries of the liver, œsophagus, and stomach; the corresponding veins entered the portal system. Mudge concludes with the following statement: "Whether the close correspondence between the remarkable condition herein described as abnormal for the frog and that apparently normal for certain ophidians be indicative of anything more than mere coincidence, further investigation can alone determine."

The results of further investigation indicate that the occurrence of pulmonary branches of the aorta in the various classes of vertebrates has an embryological rather than an evolutionary significance. The connective tissue pathway being provided, capillary branches from the adjacent vessels will enter it, and occasionally, as in these *Necturus* specimens, certain of them will become very large, and notable as anomalies.

¹⁰Journ. Anat. and Phys., 1901, Vol. 35, pp. 323-329.

¹¹Anat. Anz., 1900, Vol. 18, pp. 122-123.

¹²Journ. Anat. and Phys., 1898, Vol. 33, pp. 54-63.

REPORT OF THE SUB-COMMITTEE ON ANATOMY TO
THE COUNCIL ON MEDICAL EDUCATION OF
THE AMERICAN MEDICAL ASSOCIATION.

APRIL, 1909.

C. R. BARDEEN.

In the Record, Vol. II, No. 9, Dec., 1908, p. 425, a brief statement was made of the purposes of the committee of one hundred appointed by the Council on Medical Education of the American Medical Association to consider the medical curriculum in schools demanding at least one year of college work in physics, chemistry, biology and language for matriculation. The sub-committee on anatomy consisted of Professors G. A. Piersol, F. P. Mall, I. Hardesty, G. S. Huntington, J. P. McMurrich, A. C. Eycleshymer, T. G. Lee, C. M. Jackson, G. Carl Huber and C. R. Bardeen, chairman. The questions outlined in the Record were discussed by correspondence with the various members of the committee and were considered at an informal conference held at the time of the December meeting of the Association of American Anatomists. In response to the notice in the Record replies were received from several anatomists, including Professors A. W. Meyer, B. L. Myers and Robert Bean. Prof. Irving Haynes furnished an extensive account of the work in gross anatomy at Cornell. From the data thus gathered a report on the teaching of anatomy was compiled, submitted to the various members of the sub-committee on anatomy, revised, and presented in abstract to a joint committee composed of the chairmen of the various divisions of the Committee of One Hundred and of the members of the Council on Medical Education. It was, in part, finally read at the annual Conference on Medical Education held by the Council on Medical Education at Chicago, April 5.

Two meetings of the joint committee were held, one at New York, in December, and one at Chicago preceding the conference.

Practically the whole session at each meeting was spent in trying to adjust, to a four-year curriculum of reasonable proportions, the claims of the various sub-committees for time for their various subjects. The Council started out with the assumption that in general the medical curricula of our medical schools are overcrowded and are not in all cases well proportioned. The various sub-committees were therefore requested to consider the minimum number of hours in a 3600-hour curriculum which should be devoted to the subjects they were appointed to consider. At the first meeting of the joint committee it was found that the total number of hours requested by the various sub-committees instead of amounting to 3600 hours, amounted to over 4500 hours. It was not found possible to get a general agreement concerning the reduction of the number of hours devoted to each subject so as to formulate a 3600-hour curriculum and it was decided to proceed on the basis of a 4000-hour curriculum. A provisional number of hours, on this basis, was allotted to each subject. The provisional schedule was referred back to the various sub-committees and at the second meeting of the joint committee a schedule amounting to 4345 hours was discussed. This was finally reduced to 4100 hours. The 4100 hours were regarded as the maximum number that should be definitely prescribed for a four-year course. Instead, therefore, of defining a minimum curriculum the joint committee finally determined a maximum curriculum. It was the unanimous opinion of all present that it would be a grave mistake to try to prescribe identical curricula for all medical schools; that freedom in schedule making in different schools is an imperative necessity if progress is to be made and that the schedule adopted by the joint committee is meant merely to be suggestive. At best it is a compromise arrived at between the chairmen of the ten sub-committees and the members of the Council during two brief meetings.

It may be of interest to compare the schedule finally adopted by the joint committee with the provisional schedules of this committee, with the present schedule of the Association of American Medical Colleges and with the revised schedule proposed at the last annual meeting of the Association.

TABLE I.
NUMBER OF HOURS ALLOTTED TO THE CHIEF SUBDIVISIONS OF THE
MEDICAL CURRICULUM, IN

SUBJECTS	Schedule Assoc. Amer. Medical Col.	Proposed Revised Schedule	Schedule N. Y. Meet. Joint Com.	Prov. Schedule Chic. Meet. Joint Com.	Final Schedule Chic. Meet. Joint Com.
Anatomy, including Histology and Embryology.....	630	750	600	760	700
Chemistry*.....	300	420	300	300	280
Physiology	300	240	250	270	250
Bacteriology and Pathology	380	405	500	500	500
Pharmacology and Materia Medica.....	120	185	120	160	160
Therapeutics.....	90	?	80	80	80
Medicine, including Pediatrics and Nervous Diseases.....	1040		950	945	890
Surgery (including G—U)	600		650	700	650
Obstetrics.....	160		200	280	180
Gynecology.....	160		†	†	60
Eye, Ear, Nose and Throat.....	120		150	150	140
Dermatology and Syphilis	40		90	90	90
Public Health and Medical Jurisprudence	60		110	110	120
	4000		4000	4345	4100

*In the schedule of the Association of American Medical Colleges, chemistry includes inorganic as well as organic and physiological chemistry. In that of the American Medical Association inorganic chemistry is not included since this is assumed to be required for matriculation.

†Included here with obstetrics.

In the majority of the better medical schools of the country over 800 hours, about a fifth of the curriculum, are devoted to the anatomical sciences. There is undoubtedly at present a desire on the part of those teaching other branches to curtail anatomy so that more time may be given to those branches. The curtailment of anatomy to 630 hours in the 4000-hour curriculum of the Association of American Medical Colleges has, however, not proved satisfactory, and in the new curriculum proposed at the last annual meeting the number of hours for anatomy has been raised from 630 to 750. The 20 per cent. leeway allowed in each subject in the curriculum of the Association of American Medical Colleges makes this 4000-hour schedule elastic when it is taken in the right spirit and not rigidly applied. With 20 per cent. leeway the minimum allowed for anatomy in the new schedule would be 600 hours and the maximum of specified work might be 900 hours. These figures seem to me reasonable.

I believe, however, in a curriculum in which specific requirements are made in as few subjects, and in these subjects in as restricted a manner, as is consistent with a fair breadth of training. It is obviously impossible for the student in four years to become really proficient in each of the great branches included in the medical curriculum. He should gain some conception of the principles underlying each of these branches and should gain real proficiency in some one or two of them. Only thus can he acquire depth of understanding and the habit of thoroughness, only thus can he be made efficiently self-reliant. The twice repeated three months' lecture course of a generation ago had the advantage that it left time to the better students to develop themselves freely and independently during the other nine months. Good men were thus produced in spite of limited facilities. Give the student good facilities for work, freedom and encouragement, and the problem at once becomes not how to get him to work more, but how to prevent him from overworking.

Another advantage of having the required work reduced to a minimum is that it forces the teacher to discriminate carefully between the essential and the non-essential, and to emphasize prin-

ciples rather than details in the required courses. On the other hand the teacher is forced to keep up a keen, active interest in his science if he is to attract students to his department to do advanced work. He must be an investigator in order to keep up that spirit of scientific enthusiasm which alone makes a laboratory or a clinic attractive.

Believing thus in freedom for the development of the student and of the teacher I took at the first meeting of the joint committee a stand for a schedule of minimum requirements. I suggested a 3000-hour defined curriculum in which anatomy should have 600 hours. In such a curriculum the student who desired could elect other courses in anatomy than those required. The 600 hours in anatomy was acceptable to the chairmen of most of the other sub-committees, but a curriculum limited to 3000 hours was not. The result was a 4000-hour schedule in which anatomy was limited to 600 hours. In such a schedule the student who desired to elect more anatomy would have little opportunity to do so. At the Chicago meeting the amount of time finally allotted to anatomy was 700 hours in a 4100-hour curriculum. I believe 700 hours a fair requirement for anatomy in a 3600-hour schedule permitting of elective studies and work outside of scheduled hours. I believe that in a 4100-hour curriculum where obviously little freedom is allowed for extra work, 700 hours is proportionately too small an amount of time and that 800 hours would be a fairer allotment for anatomy.

The proportionate amount of time which should be allowed anatomy depends upon the relative value of anatomy in medical education. This in turn depends upon the importance of anatomy in developing the capacity to solve the problems presented by disease.

Of the various subjects in the medical curriculum, gross anatomy is the most concrete, the most definite in its relations to practical medicine and the easiest to supply with abundant material. The student in a good course in practical anatomy forms a direct familiar acquaintance with the intricate structure of the human body and becomes skilled in the use of instruments. Familiarity with human structure is essential for physical diagnosis, and hence is funda-

mental for scientific treatment. The skill gained in dissecting is an aid in every branch of medicine. It is certain that if a student does not dissect enough to acquire skill and does not study anatomy enough to become familiar with the body, infantile and youthful as well as adult, he will be seriously hampered in medical practice.

Microscopic anatomy is important for real understanding of gross structure. It is essential for physiology, pathology and clinical diagnosis. It therefore is, like gross anatomy, of fundamental value in medicine. Its educational value is increased by the fact that for it, as for gross anatomy, an abundant supply of excellent material may be readily furnished the student.

Embryology is scarcely less important. It offers the medical student his best opportunity to get some understanding of the phenomena of growth, the most basal thing in life. It gives abundant opportunity for experimental work.

Neurology is so important that it has acquired the dignity of a separate branch. Since man is so essentially a creature of nerves and brain it is obvious that some real understanding of the structure of the nervous system is essential for the scientific physician.

These fundamental anatomical sciences, gross and microscopic anatomy, embryology and neurology can be readily well taught. They cannot be quickly assimilated. The student must have plenty of time to dissect, to draw, to think over his work, to compare one part with another and a dissected part with cross sections, if he is to acquire familiarity with human structure and to learn to think anatomically. He must have plenty of time to prepare and study microscopic specimens and to compare microscopic with macroscopic structure if he is to get much real benefit from microscopic anatomy. He must have time to watch ova develop into embryos as well as to follow microscopically successive stages of development in prepared specimens if he is to get some understanding of growth. He must devote long hours to patient study if he is to get any real insight into the structure of the central nervous system. If the student has become thoroughly grounded in these branches he will have a definite and firm foundation upon which to rear an understanding of human medicine. If he has not this foundation he

is likely to lack security and stability in his subsequent studies and work.

The statement is sometimes made that knowledge of function is more important to the physician than knowledge of structure, and that therefore anatomy should be reduced in amount in order that more time may be devoted to physiology. One can study human anatomy in the laboratory. Opportunities for the study of human physiology in the laboratory are limited. The bedside during the study of clinical medicine often offers more. Even mammalian physiology must at present be studied by students in a greatly restricted way in most schools, since public opinion has not yet been educated to the value of vivisection in medical training. In this respect physiology stands to-day almost where human anatomy did a century ago in the times of body snatching. Could laboratory courses in mammalian physiology be offered with perfect freedom as to use of animals, it is possible that many anatomical facts now learned in the dissecting room could be picked up incidentally as a part of physiological experiments. As it is, a considerable part of physiology consists of deductions from anatomical facts, and much of the rest consists of knowledge gained by experiments not practical for repetition by the student. The field of practical physiology is at present very limited so far as laboratory work for medical students is concerned.

On the other hand in the courses in the anatomical laboratory the physiological aspects of the subject may with great advantage be emphasised. In embryology the physiology of growth may be taken up. In the study of the skeleton, muscles and joints considerable attention may be given to the simpler mechanics of motion. In the study of the gross and microscopic structure of the viscera and the nervous system many physiological data may be learned. Thus a good groundwork for the more technical aspects of physiology is gained. The committing of text-book detail to memory should be given up in favor of these broader aspects of the subject.

I believe, however, that what we as anatomists should stand for is not the retention of a large number of required hours for the anatomical sciences in the medical curriculum, but for a curriculum

in which in each of the fundamental branches there is small amount of required work and abundant opportunity for the student to do much more than the required work. The value to the physician of thorough work in the anatomical sciences will certainly manifest itself where such a curriculum prevails and will insure abundant enthusiastic work in anatomy. We must not, on the other hand, permit anatomy to be unduely curtailed by too extensive time requirements in other departments.

In the following report of the sub-committee on anatomy I omit the introduction, which covers much of the ground just reviewed. I also omit some details not likely to be of interest to professional anatomists. The report in full, together with a summary of the opinions of the individual anatomists who contribute to it, is to be published by the Council on Medical Education.

REPORT OF SUB-COMMITTEE ON ANATOMY TO THE COUNCIL ON
MEDICAL EDUCATION OF THE AMERICAN
MEDICAL ASSOCIATION.

(A) *Essential pre-requisites for the anatomical sciences of the medical course.* Required preliminary work of college grade in physics, chemistry, biology and modern language is of especial advantage to anatomy. Anatomy comes at the beginning of a student's course in a medical school, and unless the student has had adequate preliminary training he must first learn how to work before he can begin to make headway in the science. The well-prepared student can do more intelligent work a few weeks after he enters the course than most ill-prepared students can toward the end of the course. The latter are apt to become lost in a maze of detail from which they can derive no meaning. Two years of preliminary college work is far preferable to one year.

Of the preliminary courses the one most directly important for anatomy is a laboratory course of college grade in biology. A well-equipped laboratory is essential for an adequate course. There should be facilities for keeping living plants and animals of various types and the equipment should include an outfit for teaching the microscopic as well as the gross anatomy of plants and animals.

While the course should include some training in botany, the main stress should be laid upon zoology. Courses in comparative anatomy and in comparative embryology are advisable, but not necessary. The physiological as well as the morphological aspects of plants and animals should be emphasized. If the student studies the structure of the lower animals with especial reference to their activities he will subsequently find it the easier to take up the study of human structure from the standpoint of function, the standpoint of greatest importance to the physician.

(B) *The place of the anatomical sciences in the medical curriculum.* The first half of the first year of the medical curriculum should be devoted chiefly to gross anatomy and to histology. These subjects should, so far as possible, be co-ordinated. In the second half year histology may be followed by neurology and embryology. Gross anatomy may be continued throughout the second half of the first year or may be taken up again in first half of the second year. Topographical and applied anatomy may be taught in the second and subsequent years of the course. The majority of the committee believe that the required osteology, dissection, histology, neurology and embryology should be completed during the first year, leaving the second year for topographical and applied anatomy and elective work.¹

(C) *Required and elective subjects.* Courses in gross human anatomy and in histology should be required.² Courses in embryology, neurology and topographical anatomy may be elective in an elastic curriculum, but should constitute a specific part of a 3600- to 4000-hour defined curriculum. If courses in embryology, topographical anatomy and neurology are not required, the elements of these subjects should be included in the courses in histology and gross anatomy. Various advanced and special courses may be

¹Professors McMurrich and Piersol believe some dissection should be required in the second year. Professor Hardesty would place neurology in the second year.

²In addition, Professor Piersol would require courses in embryology, neurology and applied anatomy. Professor Eycleshymer would require a course in embryology. Professor Hardesty would require one in neurology.

offered as electives. It is certain that no department of anatomy can meet the minimum requirements for medical students if it is not prepared to give much more than minimum opportunities for meeting these requirements.

When the medical school is fortunate enough to be a real and integral part of a university the anatomical department, or institute, may well provide not only courses for medical students, but also premedical courses in comparative anatomy and advanced courses for zoologists, and the work of the university in vertebrate anatomy may be concentrated in this department. Such a department should be centrally connected with the medical school, but should have close affiliations with other colleges and departments. Concentration of this kind adds both to economy and efficiency.

The work offered may comprise courses in

- (a) Comparative vertebrate anatomy.
- (b) Human and comparative osteology, including special provision for courses for dental students and for students of anthropology and paleontology.
- (c) Dissection and systemic human anatomy.
- (d) Topographical anatomy.
- (e) Anatomy as applied in medicine, surgery and the specialties.
- (f) Microscopic anatomy and histology, human and comparative.
- (g) Embryology, human, comparative and experimental.
- (h) Neurology, human, comparative and experimental.
- (i) Anatomical technique: (1) Gross, including injections, corrosions, etc.; (2) General microtechnique; (3) Special technique (blood, etc.); (4) Illustrative work, including drawings, reconstruction methods, etc.
- (j) Investigation of anatomical problems, including methods of looking up the literature on a subject.
- (k) Seminars, discussion of advances in anatomy.
- (l) History of the development of the anatomical sciences.
- (m) Artistic anatomy.

While an "ideal" anatomical institute with a director and provision for all the branches mentioned is desirable, it is not essen-

tial for the teaching of anatomy in a medical school. It is, however, essential that the courses in gross anatomy should be closely co-ordinated on the one hand with those in microscopic anatomy and embryology, and on the other hand with topographical and applied anatomy. It is also essential that in addition to the work required of every student there should be elective courses and opportunity for advanced work.

(D) *Qualifications of instructors.* The supervision of work in a department of anatomy in a medical school should be in charge of persons who have had a thorough professional training in the various branches of anatomy and who have demonstrated ability in teaching and research. They should have acquaintance with anatomy as applied to medicine and surgery. They should devote their entire time to teaching and investigation, and should be provided with ample time and facilities for doing both. The traditional bad name for dullness which anatomy has born among medical students in this country has been largely due to the fact that it has too often been taught by men who have known it only as a dead science. Unless the teacher is playing at least a small part in the growth of the science he is teaching he is not likely to have an intimate acquaintance with its more vital aspects. The teacher should therefore have opportunity to devote himself to investigation. On the other hand it is important that the teaching in the main fundamental courses and especially the laboratory work, including dissection, be directly in charge of the leading members of the staff and not intrusted to inexperienced assistants. In addition to the professor in charge there should, in general, be enough instructors and assistants to provide one for each twelve to fifteen students in a laboratory course. A strong leader may get along with a smaller number of assistants, but an adequate teaching force is essential for thorough efficient work.

While the fundamental work should be directly in charge of the leading members of the staff, many of the elective courses can be put into the hands of less experienced instructors. It is desirable that each instructor give an independent course of this nature, since it serves to show his capacity and aids in his development as a

teacher. If successful, a young teacher may inspire much wholesome enthusiasm in his students.

Courses in applied anatomy may be taught by competent clinicians, but should be taught by them in the anatomical department.

(*E*) *Methods of instruction.* The chief essential is the able instructor, professionally trained in anatomy. Various methods of instruction will yield good results when employed by capable teachers. Courses should be arranged so that the student may concentrate the greater part of his energies on the anatomical sciences during the period when he is mastering the essential principles of human anatomy. This so-called "concentration method" was urged half a century ago by Von Baer and has since been recommended by several of the greatest teachers of anatomy, including Waldeyer (see Mall, "On the Teaching of Anatomy," *Anatomical Record*, 1908).

Abundance of good material is necessary. The equipment may be simple, but should be adequate. Lectures and quizzes may be utilized according to the pedagogical ideals of the instructor, but should be ancillary to the laboratory work. The student, however, should not be allowed to content himself with mere mechanical laboratory work and with committing details to memory. He should get some understanding of general principles, some insight into methods of classification, some idea of the development of anatomy as a science and some knowledge of the relations of the science to medicine. He should gain concrete ideas of structure so as to become able to "think anatomically." He should be made to feel that he is studying an intricate and delicate mechanism which subsequently he will be called upon to set right when it gets out of gear. To do this he must gain a thorough understanding of biological mechanisms in general and of the human mechanism in particular.

Careful, thoughtful dissection of the human body is the chief essential of the work in gross anatomy. Atlases and text-books should be kept close at hand by each student, and he should frequently turn to these for information and guidance. In most of the better American anatomical laboratories the method of coordinate systemic dissection is adopted. The skin is first removed

and then the superficial fascia. In the latter the superficial nerves and blood vessels are carefully studied. In the dissection of the deeper parts the vascular and peripheral nervous systems are worked out in conjunction with the organs to which they are distributed. While fat and areolar tissue are removed freely the attempt is made to keep the more definitive structures in as near their natural relations as possible. The text-book, models, special preparations and charts, recitations and the final study of the dissected part are relied upon to give the student a clear conception of each of the great organ systems. A brief study of osteology may precede the dissection, but during dissection the student is constantly referred to the skeleton as a topographical basis and thus he becomes better and better acquainted with it. At the end of the dissection the soft parts are removed and the articulated skeleton is studied. Reference to cross sections during the course of the dissection is a great aid in emphasizing structural relations.

In the course in microscopic anatomy it is usual to study a fairly extensive series of microscopic sections from the chief organs of the human body. In addition to this, in the better laboratories, fine dissection of fresh and hardened tissues and organs, under low as well as high magnification, forms an important part of the work. The aim is made to co-ordinate carefully the structure revealed by the microscope with the gross anatomical structure of tissues, organs and systems. The dissection of a small mammal or an embryo may be utilized to co-ordinate the various organs and systems with the body as a whole. The elements of microscopic technique should be taught, but the student's time should not be wasted by too great a devotion to routine mechanical procedures.

In embryology the work may begin with a study of the general processes of vertebrate development as illustrated by the eggs of the frog and the chick. For medical students, however, a relatively large part of the course should be devoted to organ differentiation and histogenesis in mammals and man. Some experimental embryology should be included in the course. Regeneration in some of the lower forms may also be studied.

In neurology careful dissection of the formalin hardened human brain and cord should be associated with the study of a good series of microscopic sections of the central nervous system. Study of the organs of special sense may form a part of the course in neurology. The study of microscopic sections of the eye, ear and nose should be correlated with dissection of the organs of some mammal.

In topographical anatomy cross sections and special preparations of formalin hardened bodies should occupy the chief attention of the students. Regional anatomy studied on the living model adds much to the interest of such a course.

Drawing is a valuable aid in stimulating the attention and sharpening the powers of observation of students of anatomy. It is commonly required in courses in microscopic anatomy. Simple semi-diagrammatic drawings, if accurate, are equally valuable requirements for courses in gross anatomy. Elaborate drawings, on the other hand, are apt to involve too much thoughtless expenditure of time in mere mechanical procedures. Clay modeling is found by some teachers of much value, especially in the study of osteology. It is apt, however, to involve the risk mentioned in connection with elaborate drawings.

(*F*) *Necessary laboratory equipment.* Under equipment for the department of anatomy are included: (a) quarters, (b) furniture, apparatus and supplies, (c) models and charts, (d) special preparations and (e) library.

(a) *Quarters.* Ample space should be provided for practical work in gross human and microscopic anatomy. There should be a lecture room, rooms for the members of the staff, for advanced work, for museum and library, and for storage. Good toilet and dressing rooms should be provided. We may specify in more detail certain of these requirements.

1. Gross human anatomy. Enough laboratory space should be provided to enable the student to do careful dissecting. Arrangements should be made to prevent disturbance of a dissection during periods when the dissector is not in the room. The rooms should be finished, furnished and cared for in a manner to inspire a sense of refinement in the student. A series of small dissecting rooms,

accommodating from one to three or four dissecting tables, is now preferred by many instructors to a single large dissecting room. Quiet, orderly work is thus much fostered. The dissecting room should be provided with hot and cold running water and be furnished with locker space in which students can put their apparatus, books and dissecting room clothing at the end of the day's work. It is desirable, if possible, that these lockers be placed adjacent to, but not in, the dissecting room itself. The dissecting rooms should be well lighted both by sunlight and by artificial light.

There should be rooms for the preparation and preservation of cadavers, and for maceration and cremation of dissected parts.

A valuable adjunct to the dissecting rooms is a study room in which special preparations, models, etc., are kept. Such a study room should be of ample size for accommodating a class in topographical anatomy.

2. For microscopic anatomy and embryology well lighted laboratory space should be provided. It is desirable, but not absolutely essential, that the major part of the light come from the north. The laboratory should be sufficiently large to provide well lighted space for all students in it at any given time. The work in microscopic anatomy and embryology lends itself more readily than gross human anatomy to teaching classes in sections which in turn use the same laboratory.

A study room in which a reference collection of microscopic specimens, special preparations and models are kept, is a valuable adjunct to the general laboratories for microscopic anatomy and embryology.

In connection with these laboratories there should be a room in which the material for the class is prepared. Such a room should be well lighted, be provided with gas and hot and cold water, and with a good equipment for microscopic technique.

3. If desired, lectures in anatomy may be given in the laboratories, so that a special lecture room is not absolutely essential. It is, however, a convenient adjunct. The seats should be so arranged that demonstrations may be readily observed from any part of the room.

4. The members of the staff should be provided with private quarters suitable not only for office work, but also for carrying on scientific investigation. Other rooms in which advanced work in anatomy and research can be carried on are a valuable adjunct. The preparation rooms can, however, be utilized for advanced students.

A photo-micrographic dark room is of great value. This should be provided with a photo-micrographic outfit and a camera and lens for copying and enlarging, making lantern slides and photographing gross specimens.

5. In addition to the working collections provided for in the study rooms mentioned above, a large museum containing preparations illustrating human and comparative anatomy is an important, if not absolutely essential, adjunct to an anatomical department. It should contain merely well selected specimens and not be "a reservoir for dumping a miscellaneous lot of stuff."

6. The department should be supplied with ample library facilities. Unless the general library of the medical school is readily accessible from the quarters occupied by the anatomical department, a special room should be set aside for a departmental library.

(b) *Furniture, apparatus and supplies.* There should be an ample supply of furniture, including book-cases, museum-cases and cabinets, to accommodate the students and the members of the staff.

The apparatus required is in part general and in part special. It should be sufficient not only for class room work, but also for making good anatomical preparations, for advanced work and research.

For gross human anatomy there should be enough disarticulated skeletons to provide the students freely with bones. There should be an ample supply of well-embalmed bodies, so that each student may be furnished half a body for dissection. Six students are as many as should dissect upon a single body at one time. There should be a sufficient supply of cross sections to offer every student an opportunity to use them for the study of regional anatomy.

The dissecting rooms should be provided with dissecting tables of convenient height and width and with reading stands for holding

text-books. The students should be furnished with chairs or stools, so that they do not have to stand all the time they dissect. They should be given wrapping cloth and preserving fluids with which to keep the parts dissected in good condition. The study room should be supplied with metallic boxes or other receptacles for moist and wet specimens, including cross sections, special preparations and dissected parts.

In the preparation room there should be an injecting apparatus of such a nature that the fluid may be forced into the body under an even pressure. This is afforded either by a water blast or by a gravity tank. The room should contain one or more embalming tables and a tackle and clasp for handling cadavers. The room for preserving cadavers may be provided with a cold storage apparatus, but this is not necessary unless a large number of bodies are handled. If the bodies are well embalmed they may be preserved in vats or metal-lined boxes or in water-proof sacks.

The apparatus for maceration of parts may be simple, but should be well ventilated. A furnace in which forced draft can be obtained either by gas or by other means is necessary for the proper cremation of parts.

For microscopic anatomy and embryology there should be a good supply of prepared and mounted sections which can be loaned students or demonstrated to them. In addition there should be a supply of material which may be given the students. There should be a laboratory assistant to prepare sections for the classes, including all steps in technique except mounting of specimens on the slides. The members of the class are thus provided with specimens of uniform excellence. It is probably a mistake to try to give students to keep specimens requiring difficulty in preparation. Specimens of this nature should be merely loaned for study. There should be an adequate supply of compound and dissecting microscopes. The student should provide himself with a set of simple laboratory instruments.

For embryology, in addition to the apparatus required in histology, special sets of serial sections of embryos in various stages of development and a collection of mammalian and human embryos

and fetuses, in part dissected, are essential. Frogs' eggs and pig embryos preserved in formalin make excellent material for the study of the grosser features of early development. For the study of the development of the hen's egg an incubator of some sort is required.

For neurology a special section cutter for the brain is of great value.

(c) *Models and charts.* For gross human anatomy models of papier maché, of plaster and of wax are of considerable value. Such models are essential for the study of structures difficult to appreciate in gross dissection because of their minuteness, such as the finer structure of the larynx, brain, eye, ear, tongue, central nervous system and the nerves of the head. Models illustrating the comparative anatomy of various structures are also of value.

In histology models are useful in illustrating the minute structure of intricate regions, such as the organ of Corti and various parts of the central nervous system. They are also of great value in giving an idea of the third dimension of various other microscopic structures, but unfortunately accurate models of this kind are not yet readily obtained.

In embryology the scarcity of material makes it impossible for the student to get first hand knowledge of the structure of young human embryos. The Ziegler models therefore form an indispensable adjunct to a course in human embryology. Models illustrating the development of the frog, chick and other lower vertebrates and of various organs are likewise of great value.

Charts and lantern slides are an important adjunct to lectures in embryology, histology, neurology and gross anatomy.

(d) *Special preparations.* To illustrate gross human anatomy there should be numerous special preparations. These should include skeletal preparations, cross sections of the body, and special dissections of various parts of the body.

The skeletal preparations should include well articulated male and female skeletons, adult, youthful, infantile and fetal; special preparations of the skull and bones of the head, and fixed and pliable preparations of the joints. Pathological specimens illustrating frac-

tures and abnormalities of the bones and joints are of considerable value.

The cross sections should pass through the body in various planes, and should illustrate infantile and youthful as well as adult conditions.

The special dissections should include regional preparations of the head, neck and extremities, and dissections of the eye, ear, nose, mouth, larynx, pharynx, cranial nerves, biliary system, the genito-urinary system and the central nervous system. There should be a series of preparations illustrating the viscera in infancy and youth. Specimens illustrating the distribution of lymphatics are of importance owing to the difficulty of dissecting these in the average cadaver.

For organology and histology corrosion preparations of the lungs, liver, spleen, kidneys and other organs are of great value. For embryology specimens cleared in caustic potash and glycerine are useful in illustrating the development of the skeletal system and in case of specimens which have been previously injected in illustrating the development of the vascular system and other organs.

(e) *Library.* The anatomical department should be provided with a library which should include the standard monographs and journals devoted to the subject. As already mentioned, if the main library of the medical college is not readily accessible to the quarters occupied by the department of anatomy the latter should have a special library in which files of current journals, text-books and works of reference are kept. Such a library should be readily accessible to students and members of the staff. In general, valuable sets of periodicals are best kept in the main library, where, as a rule, they will receive better care.

(G) *Auxiliary facilities.* See under F.

(H) *The proportion of didactic to laboratory teaching.* The committee is unwilling to set a fixed standard. Laboratory work should consume the major portion of the time devoted to each of the anatomical sciences. Lectures may perhaps justly take a greater portion of the time in courses in embryology, histology, neurology and applied anatomy than in gross anatomy.

(I) *The proportionate number of hours to be devoted to the anatomical sciences in a 3600- to 4000-hour curriculum.* In most American medical schools of the better grade from 800 to 900 hours, about a fifth of the curriculum, are devoted to the anatomical sciences. In the present schedule of the Association of American Medical Colleges 630 hours out of 4000 are allotted to anatomy, but the committee on medical education of that association has recommended that this be increased to 750 hours. Your committee believes that 700 hours in a 3600-hour curriculum or 750 to 800 hours in a 4000-hour curriculum would represent a fair proportion of time for anatomy. The majority of the committee believe in a medical curriculum in which the required work is kept at a minimum which will give students considerable time for elective work and independent study. They would prefer to see the defined required work for the whole curriculum kept within the original estimate of 3600 hours.³

The time allotted to anatomy will be sub-divided according to the arrangement of courses. Thus when a separate course in neurology is devoted to the gross and microscopic anatomy of the central nervous system and organs of special sense an equivalent amount of time may be taken from the courses in gross and microscopic anatomy. In the present schedule of the Association of American Medical Colleges 90 hours are given to histology, 90 to embryology, 30 to osteology and 420 to gross anatomy. In the schedule recently proposed 540 hours are given to gross anatomy, 135 to microscopic anatomy and 75 to embryology. The following sub-division of time agrees approximately with the majority of the schedules proposed by the various members of your sub-committee on anatomy for a 3600-hour curriculum.

In a 700-hour schedule the course in topographical anatomy should be taken from this list and ten hours added to the course in gross anatomy.

³Professors Hardesty and Jackson prefer a curriculum of at least 4000 hours. Professor Piersol believes it difficult to keep within a 4000-hour schedule, but that in such a schedule anatomy should have 871 hours, of which 60 should come in the third year.

Gross Anatomy	370 hours
Histology	140 hours
Neurology	90 hours
Embryology	90 hours
Topographical Anatomy.....	70 hours
<hr/>	
Total	760 hours

(K) *Cost of maintaining an anatomical department.* A few years ago the chairman of the sub-committee on anatomy obtained from those in charge of the departments of anatomy in several of our leading universities an estimate of the cost per year of maintaining their departments. Below a summary is given of the average cost of maintenance of the anatomical departments of five endowed and of four state universities. When gross and microscopic anatomy are taught in separate departments the budgets of the two departments are added together in making up the estimates. The average number of students in each class at the five endowed universities was 85, in the four state universities 80.

TABLE SHOWING THE AVERAGE YEARLY EXPENDITURES FOR THE ANATOMICAL DEPARTMENTS.

	Salaries.	Technical service.	Apparatus, etc.	Total.
At five Endowed Universities.	14,000	2,000	3,600	19,600
At four State Universities...	8,000	1,000	2,600	11,600

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BOOK REVIEWS.

EARLY ONTOGENETIC PHENOMENA IN MAMMALS AND THEIR BEARINGS ON OUR INTERPRETATION OF THE PHYLOGENY OF VERTEBRATES. A. A. W. Hubrecht, *Quart. Journ. Micr. Sci.*, Vol. 53, 1, 1908.

This important memoir consists of 170 pages embracing 37 plates with a total of 160 illustrations. As the title indicates, it represents an effort to determine more accurately the ancestral history of the vertebrates by aid of a close detailed study of the initial stages of mammalian development. It is, moreover, a "first attempt" toward ascertaining a more direct phylogeny of the Monodelphia—for the author does not regard the didelphian mammals as representing a transition phase between Ornithodelphia and Monodelphia, but as descendants from monodelphian placental ancestors.

The value of the paper lies perhaps more in its suggestiveness than in its contribution of new facts. It brings together the results of the author's own investigations and those of contemporary embryologists scattered throughout various periodicals and publications more particularly during the last quarter century. This wealth of facts the author attempts to collate in the form of several generalizations offered as good working hypotheses. The presentation of this mass of data in such easily accessible form is a very real service to embryologists; and the several novel views advanced—more or less tentatively—disclose the disputed ground and the obscure points, and thus indicate the lines for further research.

The author invites younger embryologists "to tackle wherever they can the early developmental stages of mammals or amphibia in preference to the cartilaginous fishes or Amphioxus, however much more easy the latter material can be obtained," having no doubt that mammalian embryology has yet very many surprises in store for us.

The fetal structures are regarded as invaluable guides in the

study of the evolution of the Mammalia. The most delicate indications for the determination of natural affinities are furnished by the details of ontogeny and placentation. In the light of these assumptions Hubrecht considers specially (a) the embryonic envelopes (trophoblast, chorion, and amnion) and appendages (umbilical vesicle and allantois); (b) placentation; (c) gastrulation (continued as notogenesis and cephalogenesis); and (d) the origin of the mesoderm. A re-classification of the Vertebrates is suggested (in harmony with comparative anatomical and palaeontological evidence), and the hypothetical ancestor (vermactinian) sketched.

In all vertebrates except *Amphioxus*—and more clearly in mammals—the didermic stage of the blastocyst (“gastrula”) arises by a process of delamination of entoderm from the embryonic knob. The delamination gastrula of mammals generally enters upon the later stages of ontogeny without the appearance of a distinct blastopore, though “atavistic” attempts have been described in *Tarsius* (Hubrecht), the rabbit (Keibel), the mole (Heape), the opossum (Selenka) and the shrew (Hubrecht).

All vertebrates pass through a process of notogenesis. This follows upon gastrulation and brings about the formation of the notochord and mesoblastic somites. Notogenesis is initiated by the appearance of a median ectodermal proliferation on the embryonic shield, the protochordal wedge (Hensen’s knot). The latter occurs in the identical spot where the rudimentary blastophore was located, and recalls the blastopore of invertebrates because cell proliferations commence here which give rise to mesodermic structures.

Hubrecht regards the trophoblast as a larval envelope of great antiquity present in all mammals, somewhat hidden in sauropsids and recognizable as reminiscences in *Amphibia*, *Dipnoi* and *Teleosts* as the so-called “Deckschicht.” The trophoblast is regarded as the mother-organ of the chorion and amnion, and as such indicates a more natural line of separation among Vertebrates between *Elasmo*branches and *Teleostomes* rather than between *Amniota* and *Anamniota*. This conclusion is supported by facts from comparative anatomy: (a) phenomena of ossification which reveal a close detailed homology between elements of the skull and the visceral arches of

bony fishes and higher mammals; (b) various anatomical differences between reptiles and amphibia break down in the case of very numerous important fossil forms; (c) presence of an air-bladder or lung from Teleostomes upward and their absence in Elasmobranchs. The suggestion is made that many of our Dipnoi, Ganoids and Teleosts may perhaps also have had terrestrial ancestors just as Cetacea are regarded as descendants of terrestrial mammals. The improved classification suggested to express more accurately degrees of consanguinity divides the vertebrates into four superclasses: (1) Cephalochordata (Amphioxus); (2) Cyclostomata; (3) Chondrophora (Elasmobranchii); (4) Osteophora (all the other higher vertebrates). The idea that the mammals are descended from reptilian-insectivorean ancestors is abandoned. Both Sauropsida and Mammals are thought to trace their phylogenetic history back through very early protetrapods of the Carboniferous period (amphibian-like animals) and their still earlier aquatic progenitors to vermiform predecessors of coelenterate pedigree.

A definitive chorion (Primates) or diplotrophoblast (Sauropsida) and amnion appear in all vertebrates above Amphibia. In sauropsids these two larval organs are often closely related in development. The chorion ("amniogenetic chorion," Bonnet) seems to arise from the outer plait of the amnion-fold. Many mammals (some rodents, monkeys and man) exhibit no amnion-fold. The single fact that the chorion (trophoblast) appears long before the amnion argues against deriving the amniogenesis of some mammals by a process of coenogenetic modification of phenomena as they obtain in sauropsids. It seems nearer the truth to think of the phylogenesis of these layers in the reverse order, or as originally unrelated. The question remains as to how the amnion has developed out of or along the side of the trophoblast.

Contrary to the opinions of Kölliker, Selenka, Ziegler, Keibel and others, Hubrecht would derive the mesoderm from both the ectoderm and entoderm. In the shrew, which furnishes the clearest case, the mesoderm arises from four independent sources. Homologous mesoderm sources are present under varied aspects also in sauropsids and ichthyosids. These are (a) annular zone; (b) protochordal

plate; (c) protochordal wedge; (d) ventral mesoblast. The first two are entodermal, the last two ectodermal in origin. The several sources soon become confluent. The annular zone produces the material for the area vasculosa (angioblast). The hinder part opposite the protochordal plate aids in the formation of blood vessels and blood from which the vascularisation of the connective-stalk (embryophore) of Primates is derived. The presence of such an annular zone of mesenchyme is denied by Rabe, Keibel and O. Hertwig.

The protochordal plate functions as a median mesenchyme-producing area in the entoderm. Among other things it furnishes the endothelium of the heart (Tarsius). The protochordal wedge appears at the spot which coincides with the anterior lip of the evanescent blastopore of the didermic stage. This area of proliferation builds the notochord. No evidence appears in Tarsius that the protochordal wedge undergoes a forward extension to be identified with the "head process." The apparent forward growth is explained as an elongation by material being added posteriorly to form the notochord and primitive somites concomitantly with increase in length of the embryonic shield. The ventral mesoblast source is separated from the protochordal wedge by the potential blastopore. It gives rise to the early extra-embryonic coelom and the visceral and parietal layers of the mesoderm. It also contributes to the formation of the connective-stalk.

Facts gathered from the works of various authors bespeak a complete homology between Amphibia and Mammalia in respect to the presence of four areas of proliferation for mesoderm. Hubrecht claims, moreover, to find a great amount of correspondence between these groups and the Sauropsida concerning the general features of very early mesoblastic formations. In *Amphioxus*, Legros ('07) has identified a protochordal plate and a protochordal wedge. In Elasmobranchs the four centers can be discerned. The ventral mesoblast is here identified with the so-called "Schwanzknopf." In Teleosts similar relations prevail except that the protochordal plate is here detected in a portion of the periblast.

The method of placentation as it appears in man, the anthropo-

morphae and the hedgehog is believed to be the primitive type. A cogent argument against the contrary position is the fact that a diffuse placenta is found in Lemurs, Cetacea, Edentata and Ungulates, groups anatomically widely separated. Placentation here is interpreted as degenerate or secondarily modified. Accordingly, then, there seems to be little justification for the attempt to derive the intricate and highly efficient placental arrangement of Primates and Insectivores out of the so-called primitive (diffuse) placenta of Ungulates and Lemurs. Hubrecht explains the absence of transition stages in the process of simplification between the more primitive (ape) and the secondarily modified (lemur) types, by the fact that these are secrets taken into the grave by very old probably mesozoic Mammalia. The primarily primitive type of placenta thus remains unknown; all the types of placentation represent co-enogenetic modifications and simplifications of varying degree (Apes, Tarsius, Lemurs). Other lines of simplification ended in the Ungulates (horse) and Edentata (Manis). In general the primates seem to contain the most primitive type of mammals; and man seems to have retained ontogenetic characters even more primitive than the apes or Tarsius. Thus an umbilical vesicle exclusively hematopoietic in function, a small allantois confined within a connective-stalk, an amnion in the form of a closed cavity from the beginning, a decidua capsularis and a restricted and highly specialized placenta, all characteristic of human ontogeny, are regarded as most primitive.

The following quotation may be said to summarize the main conclusion of the paper: "Viviparity and placentation have gone hand in hand with the development of allantois and amnion, and only after the two latter had appeared in the early viviparous Tetrapods of the palaeozoic period did certain side lines of development diverge from that which led up to modern Mono- and Didelphia. In these side lines oviparity again came to the front, and on them we meet the parent forms of the Ornithodelphia, Reptilia and the Aves."

H. E. Jordan.

Received for publication, April 12, 1909.

NOTES.

There is every promise of a great development of the Anatomical Department in the University of Minnesota. Prof. Thomas G. Lee has been made head of the Department of Anatomy, which now includes histology, embryology and neurology as well as gross anatomy. Dr. Robert Retzer, at present Associate at the Johns Hopkins University, has been made Assistant Professor and is to have charge of the dissecting room. The staff in gross anatomy will include Prof. Erdman, Prof. Retzer, Dr. E. R. Hare, and Dr. Disler, while that in histology and neurology will include Prof. Lee, Prof. J. B. Johnston and Dr. W. S. Nickerson. Through the action of the legislature there will be a general development of the entire university. During the past two years half a million dollars have been expended in enlarging the campus and a sum of three hundred and fifty thousand more is available for the same purpose. For new buildings a sum of over a million has been appropriated; the medical group of buildings will occupy a separate portion of several acres of the newly acquired territory on the bluffs along the bank of the Mississippi River. The new anatomical laboratory will be erected at a cost of two hundred thousand dollars. Prof. Lee is to go abroad in the early fall to visit the various laboratories and study the plans for the new department.

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AUGUST, 1909

No. 8

A DESCRIPTION OF A HUMAN THORACOPAGUS, WITH A CONSIDERATION OF ITS FORMAL GENESIS.

BY

R. H. WHITEHEAD.

From the Anatomical Laboratory, University of Virginia.

The specimen which I am about to describe was very generously given to me by Dr. Glasgow Armstrong, of Staunton, Va. To him I am indebted also for the following history:

The mother of the monster was a negress 31 years of age, who had had two previous labors, both normal in all respects. Her personal history was negative. She menstruated last on March 20, 1908. At 8 a. m., December 28, 1908, the amnion suddenly ruptured while the woman was going upstairs. She went to bed, but labor pains did not come on until about 10 o'clock. At 4 a. m., December 29, a head, a pair of shoulders, and one arm were delivered. The pains increased in severity, but as no further progress was made the attending physician called Dr. Armstrong in consultation at 10 a. m., with the statement that the child was thoroughly wedged, and could not be moved. Dr. Armstrong found one head, the corresponding shoulders, and three arms delivered; and he could feel a fourth arm. On making pressure upon the buttocks, the body of one of the components was delivered, and he could then determine definitely that he was dealing with a thoracopagus. The second head followed easily and quickly the hips of the first component, and labor was soon terminated. The patient made a normal convalescence,

and was out of bed in ten days. Thus Dr. Armstrong adds another to the list of cases of thoracopagi which have been delivered without a mutilating operation.

The specimen (Fig. 1) consists of two female fetuses at full term united by a bond of union which extends from the level of the lower borders of the manubria sterni to the umbilicus. The latter is single, measures 6 cm. in diameter, and is closed by a thin membrana reuniens containing no muscle tissue. This membrane had been torn, and a long piece of small intestine had escaped through the opening. The umbilical cord is also single, but bifurcates just before it reaches the umbilicus to send a prong to each component of the monster. A plane passed vertically through the center of the bond of union divides the monster into two symmetrical components; the one to the right of this symmetry plane I shall call A, and the one to the left B. The bodies of the two components do not face each other exactly, but their median planes form an angle with the symmetry plane, so that the bond of union is wider on one surface of the monster than on the other. This wider surface, since the faces look obliquely towards it, I shall call, for purposes of description, the anterior surface, and the opposite one the posterior surface. Thus, the distance between the nipples on the anterior surface is 6 cm., while on the posterior surface it is but 4 cm.

STRUCTURE OF THE WALLS OF THE BOND OF UNION.

In the symmetry plane in front are the second and third pieces of the sternum connected with the ribs as usual. A similar, but much narrower, sternum is present behind. Developmentally, of course, these two sterna are compounded out of equal constituents furnished by each of the two components. Thus, in the case of the anterior sternum, the half to the right of the plane of symmetry is furnished by A, the left half by B. And so also as to the muscles in the bond: the rectus to the right of the symmetry plane in front is the right rectus of A, and the left one is the left rectus of B, etc. In this specimen, owing to the large size of the umbilicus, there is a wide triangular interval between the corresponding recti.

The Abdominal Viscera. Each component possesses a stomach, normal in appearance and position, which is succeeded by a duodenum. The two duodena, however, fuse at their terminal portions to form a common jejunum, which, after a course of 20 cm., bifurcates



FIG. 1.

and sends a division to each component. Below this point both alimentary canals are normal.

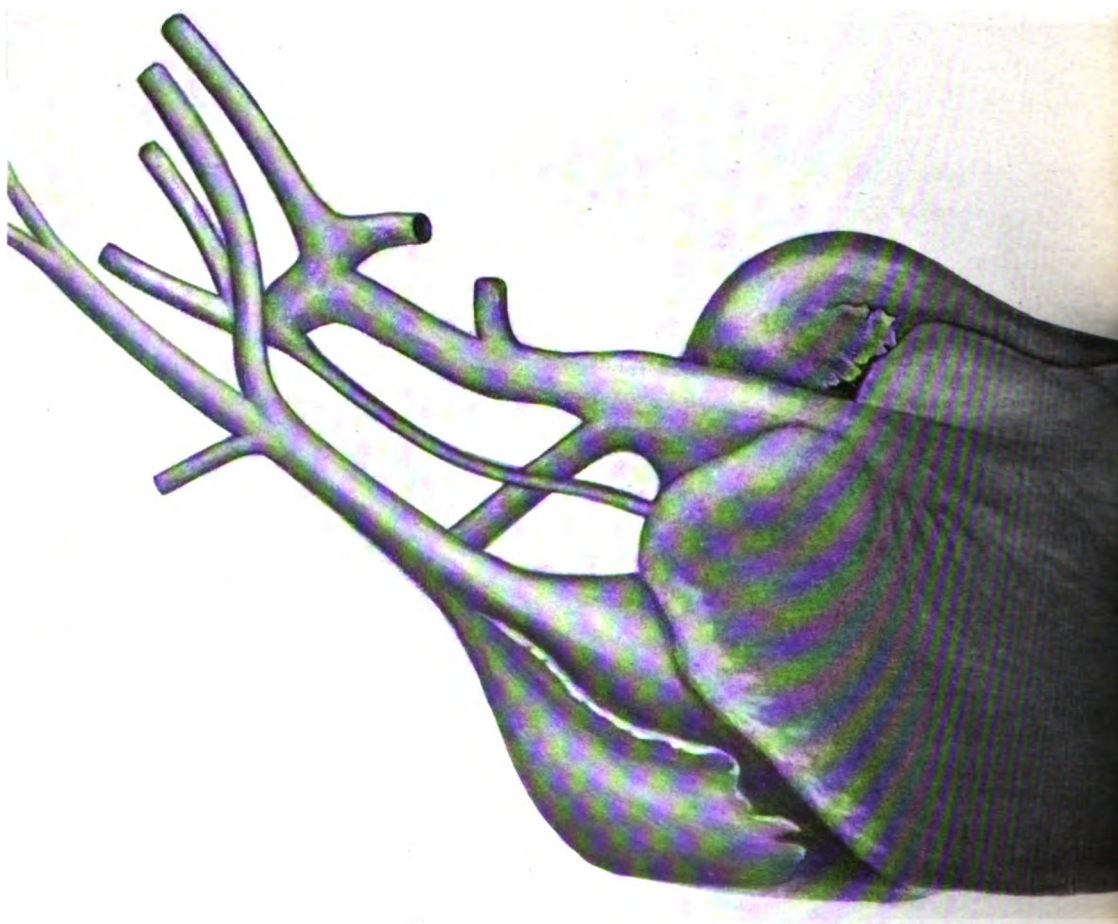
The liver is single, and lies with its long diameter in the plane of symmetry. It is formed by contributions from both A and B, and

consists approximately of the right lobe of each, the two left lobes being almost unrepresented in the completed organ. The attachment of the liver to the diaphragm, which muscle is also single, is along a plane at right angles to the symmetry plane and divides the organ into two symmetrical parts, which are, as said before, essentially the right lobes of the two components. Each lobe is crossed by a falciform ligament containing in its free margin an umbilical vein. There is no umbilical fissure, however, but the vein plunges directly into the substance of the lobe through its superior surface. On the inferior surface of each lobe is a short porta which contains the usual structures, portal vein, hepatic artery and but one hepatic duct. There is a gall bladder attached to the inferior surface of each lobe, the fundi of which look in opposite directions. The bladders taper in the usual manner to form cystic ducts, which unite with the corresponding hepatic ducts to form common bile ducts; the latter, however, open into each other making a loop under the liver, and have no connection with the duodena. Just why the connections with the duodena have been lost is not obvious. All the other abdominal and the pelvic viscera seem quite normal.

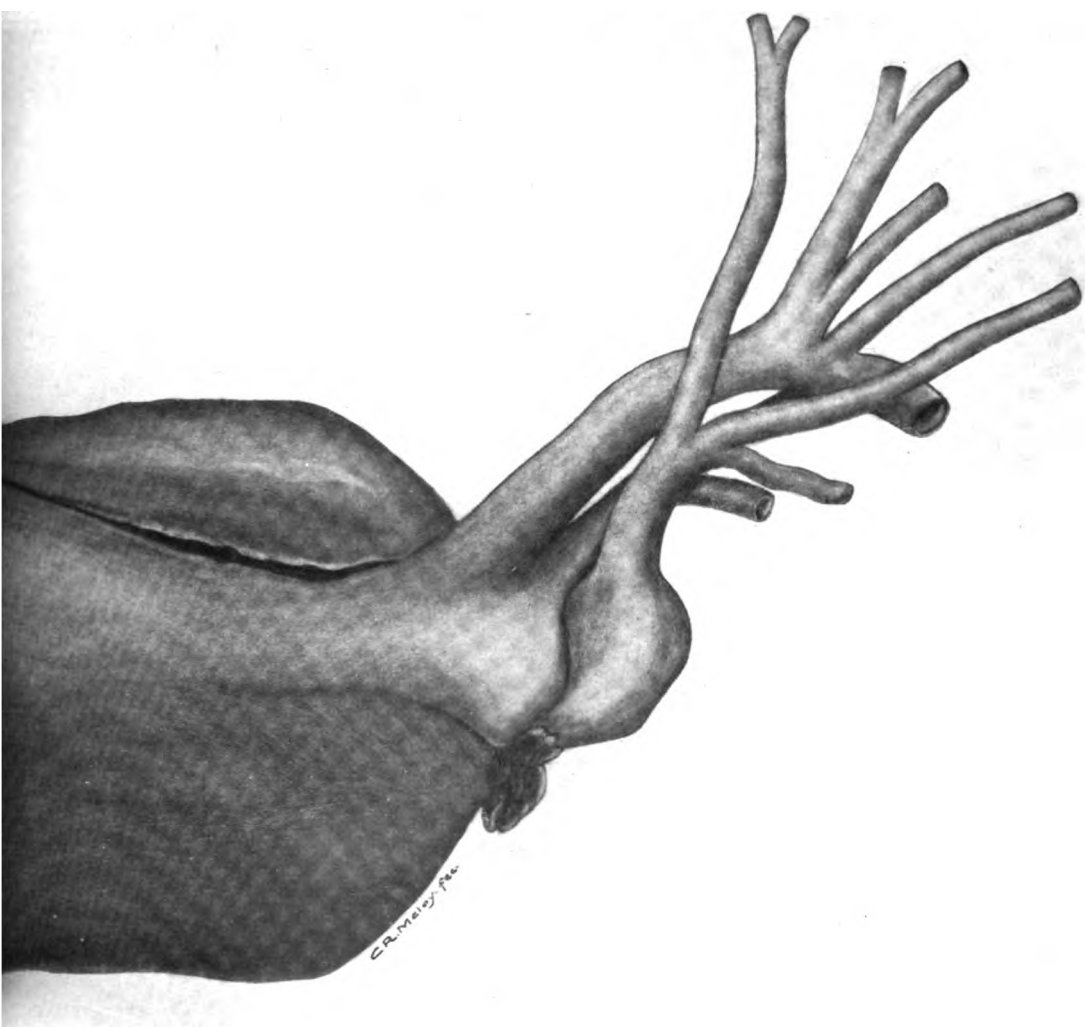
The Thoracic Viscera. The lungs, two in each component, appear normal both in position and configuration; they contain no air. The heart is the most interesting feature of the monster and is unlike any that I have found described in the literature. Inspection (Fig. 2) shows that it is compounded out of constituents from each component, and that its long diameter is transverse to the plane of symmetry. While four auricular appendages can be made out, it is seen that the auricles of the two components are united with one another. Furthermore, the auricular appendages do not occupy their normal position, but are too low, that is to say, the auricles have not been drawn as far upwards onto the base of the ventricles as happens in normal development. The portion of the heart contributed by A is dextrocardiac in position. Inspection also shows that the ventricular portions of the two hearts are united, but does not disclose the relationship of the various cardiac cavities to one another. This latter point could not be determined definitely except by studying a series of gross sections made transverse to the long diameter of the

DESCRIPTION OF A HUMAN THORACOPAGUS.

R. H. WHITEHEAD.



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heart. This study discloses the following facts: the two auricles of A are connected with those of B by a large thick-walled channel, which we may call the interauricular sinus, with the result that there is virtually one huge auricle imperfectly divided on each side of the symmetry plane into two by an interauricular septum. The arrangement of the ventricular cavities and their connections with this auricle are shown in the accompanying diagrams. Fig. 3 represents the condition in the anterior portion of the heart. The right ventricle of A and the left ventricle of B, both small, are united by a septum of muscular and connective tissue. Both open freely into the auricular cavity by means of a large auriculo-ventricular canal,

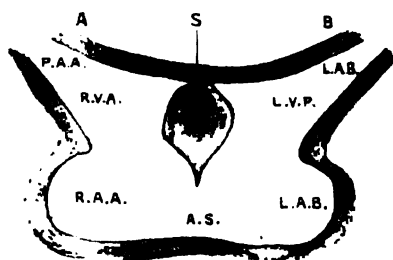


FIG. 3.

which is not guarded by valves. In the posterior portion of the heart (Fig. 4) the fusion between the two ventricles is much more complete, and there is practically but one ventricle, composed of the left ventricle of A and the right ventricle of B, opening into each other and into the common auricle. The left ventricle of A is closed at its base, having no opening into the aorta of that side, as will be described later.

The Blood-vessels at the Base of the Heart.—(Fig. 2.) In the right component (A) both the venæ cavæ are formed normally and open into the right auricle. But in B the superior vena cava is formed on the left side, and both the superior and the inferior venæ cavæ open into the left auricle. The vena azygos major of B also lies to the left of the vertebral column. The relation of the large

arteries to the heart is different in the two components. In the case of B the pulmonary artery arises from the left ventricle, the aorta from the right ventricle; in other respects these two vessels are normal. In A the pulmonary artery springs normally from the right ventricle and, after giving off a branch to each lung, continues as the ductus Botalli to join the aorta in forming an arch, from which the left subclavian artery takes origin; this arch then proceeds downward as the descending thoracic aorta. The ascending aorta is represented by an impervious cord extending from the base of the left ventricle, but not connected with its cavity; just before joining the arch mentioned above it develops a lumen, and gives off a short trunk which divides into the innominate and left common carotid arteries.

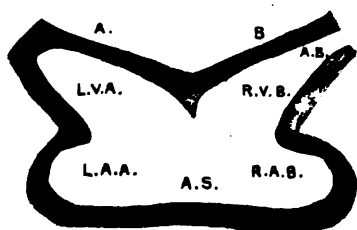


FIG. 4.

The pulmonary artery in each component and the aorta of B are provided with normal valves.

It will be noticed that there is a curious bilateral symmetry in respect to the connections of the large blood-vessels with the heart. In both components the large veins empty their blood into that auricle which is the more anterior, namely, the right in A, the left in B; and in each the pulmonary artery arises from the ventricle which is the more anterior, the right in A, the left in B.

It is evident that the circulation in this heart was quite simple. The ventricles are little more than narrow clefts unprovided with auriculo-ventricular valves, through which the blood was forced by the large auricle directly into the aorta and the pulmonary arteries without stopping in the ventricles. It is also clear from what has

been said concerning the composition of the common auricle and the openings of the veins therein that the arterial blood brought to the heart in the inferior venæ cavæ was mixed in the auricle with the venous blood from the superior venæ cavæ, and that, accordingly, mixed blood was distributed to all portions of the body by the fetal arteries. This mixed blood was quite sufficient to bring the two fetuses to full intrauterine maturity—a fact which supports the view of Pohlman¹ and others that mixing of the arterial and venous bloods in the heart is characteristic of the normal fetal circulation. And, finally, it also appears that the blood of each component was mixed with that of the other in the common auricular cavity.

Considerations as to Genesis. This specimen sheds no new light upon the causal genesis of thoracopagi or other monsters, and I shall not attempt to discuss that question. Indeed, it seems that the data at hand are far too insufficient to allow anything approximating positive conclusions. Wilder's² attractive theory that monsters are merely germinal variations from the normal may or may not be correct; it does not seem possible either to affirm or to deny it. And so also as to Mall's³ suggestion, I find it very difficult to work out a causal connection between the existence of an endometritis and the formation of a thoracopagus.

With respect, however, to the *formal* genesis of such monsters we are in much better position. Beginning with such experiments as those of E. B. Wilson and others which showed that the egg of *Amphioxus* and of amphibians could be induced by separating the blastomeres in the two-cell stage to develop two embryos, and ending with the observation of two blastoderms, or two primitive streaks, or very young double monsters on the same yolk in the fowl egg, we have a series of well-attested observations tending to show that under conditions not always understood the fertilized ovum is capable of

¹A. G. Pohlman. The Course of the Blood through the Heart of the Fetal Mammal. *Anatom. Record*, Vol. III, No. 2, 1909.

²H. H. Wilder. The Morphology of *Cosmobia*. *Amer. Jour. Anat.*, Vol. VIII, No. 4, 1908.

³F. P. Mall. Study of the Causes Underlying the Production of Human Monsters. *Jour. Morph.*, Vol. XIX, No. 1, 1908.

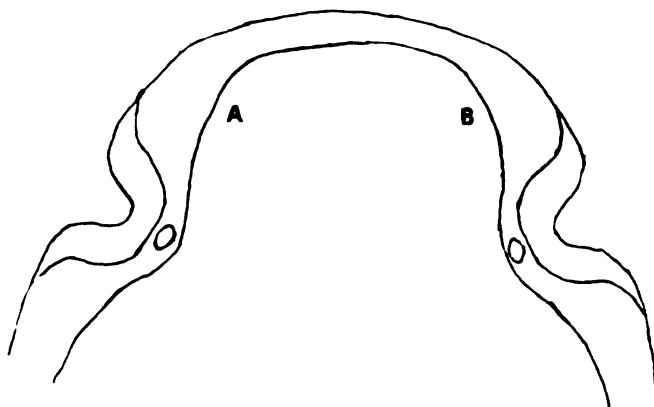


FIG. 5.

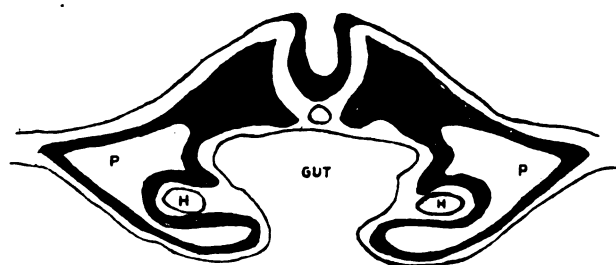


FIG. 6.

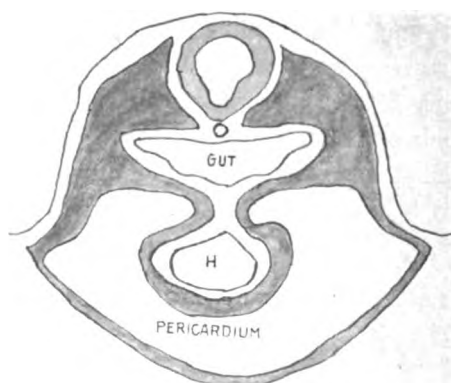


FIG. 7.

giving rise to two centers of embryo formation. Upon these facts as a foundation schemes for the reconstruction of the development of monsters have been advanced by various students of teratology, the latest of which is that proposed by E. Schwalbe.⁴ It consists, essentially, in the assumption of two formative centers in the same ovum, each of which if uninterfered with by its neighbor, would produce a perfect embryo; but under the conditions of development portions of the two embryos are brought together at a very early stage of development and more or less fusion takes place. In the remainder of this paper I wish to test this theory upon the thoracopagus under consideration.

Assuming that two centers of formation appeared in this ovum at a very early stage, we may pass at once to a consideration of the probable position of the primitive streaks. It seems clear, as has been emphasized by Kaestner,⁵ that the relative position of these structures must be of much importance in determining the configuration of the future monster, since the streak determines the position of the longitudinal axis of the embryo and of various organs. In our case, as the median planes of the two components formed an angle with the symmetry plane, it is probable that the streaks were not parallel, but were placed at an angle to the future symmetry plane. The diagram, Fig. 5, represents this condition in a later stage when the medullary grooves have formed. As is well known, the heart and pericardium are developed from a paired anlage, the two parts of which are soon brought together and fused in the median line, by which process there is also formed a floor for the foregut (Figs. 6 and 7). Starting with the condition shown in Fig. 5 it is seen that the heart regions of A and B—regions which bulge prominently on the ventral surface of young embryos—would soon be brought in the progress of their development into very intimate contact, and might easily fuse in the same way as the halves of the normal heart anlagen unite with each other. Fig. 8 represents this process of fusion as affecting only the pericardia—a condition which obtains

⁴E. Schwalbe. *Die Morphologie der Missbildungen*. Teil II, 1907.

⁵S. Kaestner. *Doppelbildungen an Vogelkeimscheiben*. *Arch. f. Anat. u. Physiolog., Anat. Abt.*, 1901.

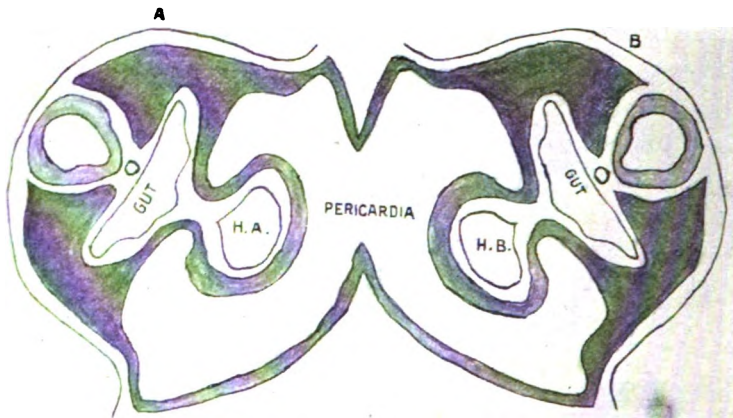


FIG. 8.

in those thoracopagi which possess two separate hearts in one pericardium. It is clear, however, that in the case under consideration fusion had occurred between the hearts as well as the pericardia, a process represented at its beginning in Fig. 9. It is evident, furthermore, that the single heart tube must have been formed both in A and B previous to fusion. For, if in Fig. 6 one imagines a similar

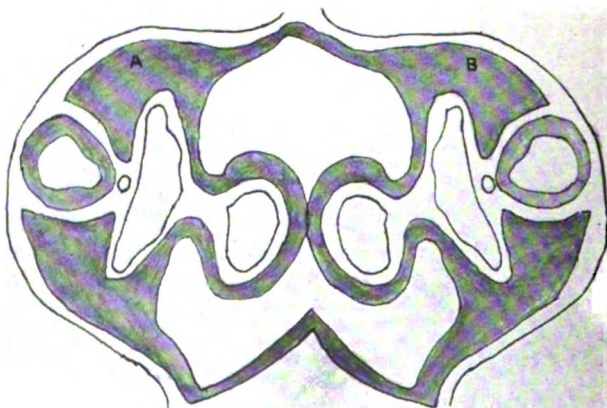


FIG. 9.

diagram placed opposite to the one there drawn, it will be seen that fusion of the paired anlagen of the two components would probably result in two hearts and two pericardia; and that these two hearts would lie the one behind the other in the plane of symmetry, a position which is just opposite of that found in our case. The intimate fusion of the auricular portions of the hearts in this case would indicate that these portions of the primitive hearts were brought into closest contact; and the more intimate fusion between the two posterior ventricles might be explained in the same way, the greater propinquity in this situation being due to the oblique position of the two bodies with reference to the plane of symmetry.

In connection with the heart we have yet to account for the anomalous relations of the pulmonary artery and the great veins to the left side of B's heart. These may be explained in some such way as follows: We have seen that in A the heart had a decided dextro position. It seems reasonable to suppose that, during the complicated twistings and rotations undergone by the developing hearts, the heart of one component might prevail over that of the other. It might well be that what is, so far as position is concerned, the left side of the heart in B was originally the right side, which was rotated into its abnormal position by the heart of A.

The conditions found in the other viscera are readily accounted for on this hypothesis of Schwalbe: the two foreguts would develop normally, being separated by the fusing hearts and livers; but below the level of the liver there would be nothing to prevent the midguts from fusing over a greater or lesser portion of their extent.

I wish to thank Mr. F. P. Smart for the photograph of the specimen shown in Fig. 1; and Prof. C. R. Meloy for the excellent drawing of the heart.

Received for publication, May 12, 1909.

A CONTRIBUTION TO THE HISTOGENESIS OF THE SYMPATHETIC NERVOUS SYSTEM.¹

BY

ALBERT KUNTZ.

WITH 2 FIGURES.

In studying embryos of the pig for the purpose of tracing the development of the sympathetic nervous system, the writer has been interested in the evidence for the migration of nervous elements from the neural tube along the fibers of the peripheral nerves. In a recent paper² I have described the migration of medullary cells, among which are to be recognized cells of an indifferent character and neuroblasts, into the dorsal and ventral nerve-roots. In transverse sections of embryos of the pig 6 and 7 mm. in length breaches in the external limiting membrane of the neural tube occur quite frequently in the region of the dorsal nerve-roots. Through these breaches lines of cells practically touching each other end to end may be traced from the mantle layer into the proximal part of the dorsal nerve-roots (Fig. 1, dnr). Further evidence for the migration of medullary cells into the dorsal nerve-roots is afforded by the fact that in many sections of embryos 6 and 7 mm. long, where no breaches occur, cells are found in contact with the external limiting membrane inside the neural tube in the region of the dorsal nerve-roots. In embryos 9 mm. and over in length this region, as shown in Fig. 2, dnr., is always occupied by fibers of the dorsal nerve-root and rarely are cells found among them.

In transverse sections of embryos of the pig from 9 to 13 mm. in length breaches occur in the external limiting membrane in the region

¹From the Laboratories of Animal Biology of the State University of Iowa.

²The Migration of Nervous Elements into the Dorsal and Ventral Nerve-roots of Embryos of the Pig. Proceedings of the Iowa Academy of Science, Vol. 16.

of the ventral nerve-roots. Through these breaches medullary cells may be observed migrating into the ventral nerve-roots (Fig. 2, vnr.). Migration of medullary cells into the ventral nerve roots of embryos of the pig has recently been described by Carpenter and Main ('07). I have been able to substantiate their observation that cells may be found "just inside the external limiting membrane, in an intermediate position half in and half out of the neural tube, and in the base of the ventral nerve-root just outside the external limiting membrane." But, whereas they have described only elongated cells which they recognize as the indifferent cells of Schaper, I have observed cells of a distinctly pyriform type migrating with the indifferent cells.

According to the researches of Schaper ('97) the germ cells (Keimzellen) of His (cells of epiblastic origin undergoing mitotic division near the internal limiting membrane of the neural tube) give rise to cells which he characterizes as indifferent. These indifferent cells migrate toward the mantle layer and are there transformed either into neuroblasts or into embryonic supporting cells. In the higher vertebrates some of these indifferent cells undergo further division by mitosis in the mantle layer.

The cells which migrate from the neural tube into the dorsal and ventral nerve-roots are of two general types; elongated cells which are to be regarded as the indifferent cells of Schaper, and pyriform cells which are to be regarded as the neuroblasts of Schaper. The neuroblasts are much fewer in number than the indifferent cells, but are distributed indiscriminately among them. When observed passing out of the neural tube the tapering end is usually directed peripherally. This also is in accordance with the usual position of the neuroblasts in the mantle layer.

The orientation of the cells in the neural tube is such that two general courses of migration into both dorsal and ventral nerve-roots may be recognized. In the ventral region some of the cells move directly outward from the ventral zone toward the base of the ventral nerve-root; others tend ventro-laterally from the region in which the lateral horn of the gray matter arises. In the dorsal region the chief course passes quite directly from the dorsal zone toward the proximal

part of the dorsal nerve-root, with some cells moving from the most dorsal region along the inner surface of the external limiting membrane. The other course tends dorso-laterally from regions ventral to the dorsal nerve-root. The cells of the latter course probably originate in the same region as those which move ventro-laterally toward the ventral nerve-root.

Further observation has shown that the cells which migrate from the neural tube into the spinal nerve-roots wander peripherally along the spinal nerves and visceral rami into the anlagen of the sympathetic ganglia. As the fibers of the ventral nerve-root emerge from the neural tube they are accompanied by medullary cells which may be distinguished from the mesenchymal cells by their size and form. Very often they also take a slightly deeper stain. As the fibers grow peripherally these cells wander along their course, while others emerge from the neural tube to take their places in the base of the nerve-root. Similar cells detach themselves from the distal ends of the spinal ganglia and wander down along the sensory fibers. Whether these represent cells which have migrated from the neural tube into the dorsal nerve roots could not be determined since it was not found possible to trace cells through the spinal ganglia. Beyond the point of union of the sensory and motor roots it is no longer possible to distinguish the cells which wander down from the spinal ganglion from those which migrate out from the neural tube along the fibers of the ventral nerve-root. The majority of the cells thus distributed among the growing fibers of the spinal nerves are cells of the elongated type. Frequently, however, pyriform cells are found among them.

In transverse sections from the dorsal region of embryos of the pig 7 mm. in length the spinal nerves have extended peripherally a little beyond the level of the dorsal aorta. The fibers are loosely aggregated. Numerous elongated cells and a few cells of the pyriform type are found among the fibers as well as at the surface of the bundle. Fibers are not yet present in the visceral ramus, but at a point a little above the level of the aorta, cells, either singly or in groups of two or three, are seen to bend from their course nearly at right angles and wander through the mesenchyme toward the dorso-

lateral angle of the dorsal aorta along the path later occupied by the fibers of the visceral ramus (Fig. 1 pvr.). At this stage the anlagen of the sympathetic ganglia are already present as loose aggregates of cells along the dorso-lateral angles of the dorsal aorta. Cells of the pyriform type were observed along the paths of the visceral rami and among the loosely aggregated cells along the dorso-lateral angles of the dorsal aorta (Fig. 1 nb.). Thus pyriform cells which are to be

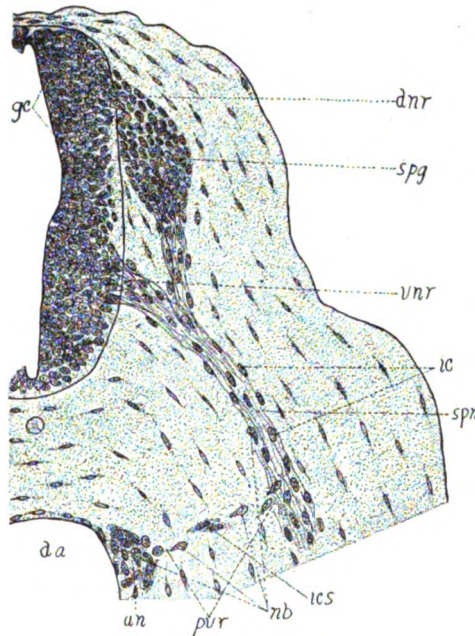


FIG. 1.—Transverse section of neural tube and sympathetic anlage of 7 mm. embryo of the pig $\times 165$. an., sympathetic anlage; da., dorsal aorta; d. n. r., dorsal nerve root; gc., germ cells of HIs; ic., indifferent cells; ics., indifferent cells in syncytium; nb., neuroblasts; pvr., path of visceral ramus; spg., spinal ganglion; spn., spinal nerve; vnr., ventral nerve-root.

regarded as the neuroblasts of Schaper have been traced from the neural tube along the spinal nerves and visceral rami into the anlagen of the sympathetic ganglia. It may further be observed that the elongated cells, both along the spinal nerves and visceral rami, may often be seen joined together in small groups by protoplasmic processes or in small syncytia. The pyriform cells, however, are always free.

In transverse sections of embryos 10 mm. in length fibers appear in the visceral rami but do not yet extend into the anlagen of the sympathetic ganglia, the cells of which have become more numerous and more closely aggregated. The distribution of the medullary cells along the paths of the nerve fibers remains about the same as in the preceding stage.

In embryos 12 and 13 mm. in length the embryonic nervous system has assumed more definite form. In transverse sections of 12 mm. embryos (Fig. 2) the fibers of the visceral rami are seen to extend into the anlagen of the sympathetic ganglia. These are still loosely aggregated cell columns but begin to show evidence of their future segmental character. As in the preceding stages numerous elongated cells are found among the growing nerve fibers and at the surface of the bundles, and pyriform cells may be observed all along the path from the neural tube into the anlagen of the sympathetic ganglia.

The destiny of cells which migrate out from the neural tube and spinal ganglia has already occupied the attention of not a few investigators. Harrison ('01) suggested the possibility that certain medullary cells which he observed migrating into the ventral nerve-roots of embryos of the salmon may wander farther peripherally, i. e., into the sympathetic ganglia, and there give rise to sympathetic motor neurones. Bardeen ('03) suggests that the cells which wander out from the spinal ganglia and cord along with the bundles of axis-cylinder processes may take some part in the formation of the neurilemma. He, however, believes with Vignal and Gurwitsch that in mammals the neurilemma is derived largely from mesenchyme. Kölliker ('05), though formerly of the opinion that the neurilemma is of mesoblastic origin, came to the conclusion in his later researches that the elongated cells which wander out from the spinal ganglia give rise to the neurilemma of the sensory fibers and that the neurilemma is everywhere of epiblastic origin. Dohrn and Neal have expressed the opinion that the cells which compose the neurilemma of the motor fibers have their origin in the neural tube and brain. Carpenter ('06) has shown that in embryos of the chick cells of an indifferent character migrate out from the ventral wall of the mid-

brain along the oculomotor nerve and become transformed into nerve cells of the ciliary ganglion. Carpenter and Main ('07) "feel sure" that some of the medullary cells which escape from the neural tube become cells of the neurilemma and there subserve a supporting func-

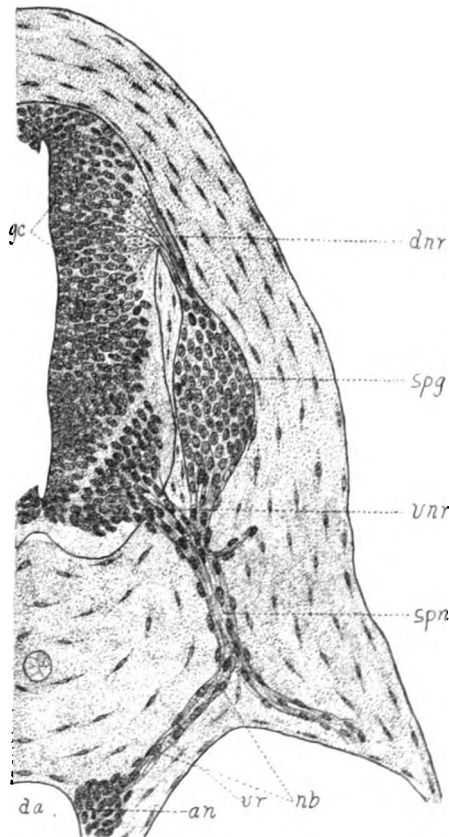


FIG 2.—Transverse section of neural tube and sympathetic anlage of 12 mm. embryo of the pig $\times 165$. an., sympathetic anlage; da., dorsal aorta; dnr., dorsal nerve root; gc., germ cells of His; nb., neuroblasts; spg., spinal ganglion; spn., spinal nerve; vnr., ventral nerve-root; vr., visceral ramus.

tion similar to that of the neuroglia cells in the central nervous system.

Thus far only cells of an indifferent character have been considered. There are, however, as shown above, two distinct types to be

recognized among the cells which migrate from the neural tube into the spinal nerve-roots. In the light of Schaper's researches we must conclude that the pyriform cells which migrate peripherally from the neural tube have already undergone differentiation and must develop into neurones. These cells having been traced along the spinal nerves and visceral rami into the anlagen of the sympathetic ganglia obviously develop into sympathetic neurones. Thus there is established a direct genetic relation between the sympathetic and the central nervous systems.

It is not the writer's purpose in this paper to discuss the fate of the elongated medullary cells found among the fibers of the peripheral nerves. Inasmuch, however, as frequent reference has been made to them they may not be passed by without brief consideration. Occasionally one of these cells is seen undergoing mitotic division. My observations do not preclude the possibility that transformations may take place along the paths of the peripheral nerves similar to those which, according to Schaper, take place inside the neural tube. However, proliferation of these cells outside the neural tube is probably not sufficient to be of any considerable importance. A large majority of the elongated cells which wander out from the neural tube and sensory ganglia probably enter into the formation of the neurilemma.

SUMMARY.

1. Medullary cells migrate from the neural tube into the dorsal and ventral nerve-roots of embryos of the pig.

2. These migrating cells are of two general types: (a) elongated cells which are to be regarded as the indifferent cells of Schaper; (b) pyriform cells which are to be regarded as the neuroblasts of Schaper.

3. These migrating cells seem to have their origin in more or less definite regions in the neural tube.

4. Both the indifferent cells and the neuroblasts wander peripherally and may be traced along the spinal nerves and visceral rami into the anlagen of the sympathetic ganglia.

5. The neuroblasts which migrate from the neural tube into the anlagen of the sympathetic ganglia develop into sympathetic neurones.

Thus, there is established a direct genetic relation between the sympathetic and the central nervous systems.

6. A large majority of the elongated cells which wander out from the neural tube and sensory ganglia probably enter into the formation of the neurilemma.

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BOOK REVIEWS.

TEXT-BOOK OF EMBRYOLOGY. By Frederick Randolph Bailey and Adam Marion Miller. New York: William Wood & Co., 1909; pp. 672; 515 illustrations.

Like other recent text-books of embryology, this one was written especially for the medical students with emphasis "upon those features which bear directly upon other branches of medicine." The authors of this book have, however, undertaken to "broaden its scope and make it of greater value to the student of embryology and allied sciences."

The volume is a good piece of book-making, as it is done in America, being printed on heavy clay paper well adapted to half-tones, in large, clear type. The illustrations are unusually clear and the references are usually printed in full instead of being represented by abbreviations explained by a legend below.

The authors have conscientiously described the development of every organ of the body with no important exceptions and have added a final chapter on teratogenesis. Each chapter is followed by practical suggestions giving the technique for the study of the subjects described in the chapter, and by a list of the more important literature for further study. To avoid repetition, there is an appendix dealing with general technique. In the chapters on organogenesis there is included a brief account of the more important abnormalities of development of the systems described. A very complete index of 33 pages concludes the book.

These are the bare statistics of this ambitious undertaking; one would wish to be able to say of such a book, at the least, that it is reliable and may be safely trusted as a guide to the subjects of which it treats; but it is necessary to record, with regret be it said, that it is not a safe guide even in many matters of fact, and that many of the generalizations are hasty and uncritical, or even absolutely

wrong. The general excellence of the illustrations, some 90 per cent of which are borrowed, weighs but lightly in the balance.

The chapter on the nervous system, which is the work of Dr. O. S. Strong, is written with critical judgment and shows evidence of good scholarship on every page; the only criticism to be passed on it in the opinion of the writer is that it is rather too abstract to be readily intelligible to the class of students for whom it is intended; but they cannot fail to profit by its study, and to the more advanced student it is delightful reading. If the other chapters had been up to this standard the book would deserve nothing but praise.

But the other chapters are characterized as a rule more by industry than by insight. This is especially shown in the first part of the work, and, indeed, in every place where knowledge of the general principles of biology and of comparative anatomy and embryology is required. When the authors reach the ground of anatomy, in the narrower sense, they move more surely.

Some examples of the above criticisms should be given. In Chapter II it is said of the frog's egg that "the dark side indicates an excess of deutoplasm"; this is evidently a slip, the exact reverse being intended. The authors then go on to say that "inasmuch as deutoplasm is heavier than cytoplasm an egg with polar differentiation, if left free to revolve as in water, will assume a definite position with the protoplasmic or animal pole above and the deutoplasmic or vegetative pole below." If the authors had studied the pelagic teleost egg, where the reverse is the case, they would not have made such a sweeping statement; their rule is honored in the breach as well as in the observance. The "membrana undulatoria or wavy membrane of Birds," p. 15 (referring to the spermatozoa), is a discovery of the authors; but perhaps Amphibia were meant.

The discussion of maturation in Chapter III is far from being illuminating or even clear. It is hard to see why if "the maturation of the male sex cells in the vast majority of forms is much more difficult of demonstration than the maturation of the female sex cells" the number of studies on the former subject should exceed by so many those on the latter. Nor can one understand why "it is necessary to consider all the generations of cells from the mature

spermatozoa back to the spermatogonia" in studying the maturation of the male cells, if the same is not the case in the female sex cells. This statement is repeated twice as a reason for the assumed difficulty of studying the maturation of the male sexual cells. The classification of types of reduction into those with tetrad formation and those without, which differ only in the fact that "each chromatin mass does not show a differentiation into four pieces" in the latter case, but does in the former, might be characterized as naïve.

In the chapter on fertilization, the occurrence of normal polyspermy "in some insects" is noticed, but its typical occurrence in some vertebrates (Selachia, Reptilia, Aves) with which the book deals, is not mentioned. The exploded theory that the so-called fertilization membrane is a protection against polyspermy is upheld.

The chapter on cleavage is inexcusably careless in many respects, but it is in the part dealing with some general features of cleavage that the best gems of thought are found: we are told that "in a spherical holoblastic egg the division plane may be in any direction, but must bisect the mitotic figure at right angles to the long axis of the spindle"; the fact of polarity, and the relation of the first cleavage plane to it, is ignored; and the first part of the above statement is absolutely wrong. The distinction between radial and spiral cleavage appears always in the second cleavage, and may appear in the telophase of the first, a fact that the authors do not appear to know. Moreover, the third division in spiral cleavage is inclined usually to the right, not to the left as the authors state. The term "morula" is no longer used by students of cleavage, except perhaps as applied to the cleavage of the mammalian ovum, and the statement that "after the morula has become fully formed there appears in it a cleft or cavity due to separation of its cells" is wrong or meaningless, as the reader chooses. "In eggs in which the cells resulting from segmentation show greater inequality in size (due to difference in yolk-content) as in the frog, the segmentation cavity is surrounded by several layers of cells"—this is true of the frog, but the generalization is absurd (cf. Clepsine).

The subject of the germ-layers (Ch. VI) is taught by comparison, homologizing the layers and the modes of their origin from Amphi-

oxus to man. This is one of the most difficult subjects in vertebrate embryology; it involves more divergent views than any other. It is perhaps unfortunate to have placed before the student an account which a trained embryologist cannot follow, but the student will at least be spared the pain of noting the frequent errors, *e. g.*, the description of the origin of the primitive streak of birds from a crescent which is said to be marginal, but was not so described by its discoverer, and is not so figured by the authors; recent exact accounts of the primitive streak are ignored, and Duval, Hertwig and Bonnet are quoted, the two former at least incorrectly; the reptiles are denied a primitive streak (p. 67). The archenteric invagination of reptiles is wrongly stated to be marginal (p. 67) though figured differently. The statements about the origin of the mesoderm in reptiles and birds is extremely confusing, leading to the conclusion that the mesoderm cells may be considered as derivatives of the protentoderm, whereas the figures show them correctly as derived from the ectoderm.

The statement that "The amniotic folds from the beginning involve the splanchnopleure" (p. 100) is another oversight; of course somatopleure is meant. In the chick the head-fold of the amnion does not begin on the first day as stated, but on the second.

P. 108. "The allantoic sac in most mammals is a very rudimentary structure"; even if the ungulates, in which the allantoic sac is very large, had been excluded, this would be a very unsafe generalization.

P. 108. "In all cases where the embryo is retained in the uterus it (the chorion) forms a most highly specialized and complex structure which in connection with the allantoic vessels establishes the communication between the mother and the embryo"; on p. 112 we are told that monotremes and marsupials are dependent for their food upon the yolk stored up within the egg and that "in these two orders the foetal membranes present essentially the same condition as in Birds and Reptiles." If we put these two statements together are we to infer that in the marsupials the embryo is not retained in the uterus? Is the student also to infer that marsupials in general have large yolk-bearing ova? Is the chorion of marsupials most highly

specialized and complex, or does it present essentially the same condition as in birds and reptiles? It is hard to say which is worse here, the confusion or the errors.

To give further citations would be tedious, and perhaps unnecessary to prove that the book requires a most thorough revision before it can be recommended as a text-book of vertebrate embryology. Apart from the above reasons for criticism, the writer cannot but feel that the method of introducing students to the study of embryology which consists in abstracting the salient points from the field of comparative embryology is pedagogically wrong, although it is the method of the great majority of text-books. If it is necessary to consider the problems of comparative embryology in an elementary text, and it may be admitted that it is at least desirable, the development of some single form should run through the book as the main stream of discussion, and it should be given in sufficient detail to stimulate the critical insight of the student; the comparative statements may be made as side branches contributing to, and expanding the main topic, and leading up to the generalizations.

F. R. Lillie.

EDINGER'S INTRODUCTION TO THE STUDY OF THE NERVOUS SYSTEM.

(Edinger, L., Einführung in die Lehre vom Bau und den Verrichtungen des Nervensystems.) Leipzig, F. C. W. Vogel, 1909.

The seventh edition of Edinger's Lectures on the Central Nervous System has quite outgrown the original purpose for which the lectures were prepared, viz., an *introduction* to the internal organization of the central nervous system adapted for medical students and practitioners. The work has become, in fact, a treatise on the comparative anatomy and phylogeny of the vertebrate nervous system not well adapted for the use of beginning students of the subject. Accordingly, the author has just published a smaller and much more elementary student's manual.

The text of this little volume of 190 pages is largely rewritten; it is not a mere condensation of the larger work. The treatment of the subject is in plan similar to that of the earlier editions of the

Vorlesungen, but with better arrangement of the matter and excellent summaries of the physiological and pathological significance of the organs described. There are a few new figures, but most of the 165 illustrations are taken without change from various editions of the *Vorlesungen*. The book has some of the elements of weakness of the seventh edition of the larger work, which has recently been reviewed at length in these columns (*ANATOMICAL RECORD*, Vol. II, pp. 273-283); but it is nevertheless a very successful elementary text-book. The graphic literary style, the wealth of pictorial illustration and the use of comparative, physiological and pathological data as aids to the exposition throughout, combine to make it a very useful manual.

The reviewer believes that a more thorough-going application of the functional analysis which in chapter 3 is applied to the spinal cord and nerves would greatly simplify and clarify the exposition of the medulla oblongata and its nerves for the elementary student. Dr. Edinger has elsewhere used this principle and it is unfortunate that he has not taken advantage of it here in his elementary text-book, where its usefulness as a pedagogical aid is greatest.

The book is sure to prove very valuable as a reference work in medical courses in neurology and it should have a wide circulation in this country as well as in Germany.

C. Judson Herrick.

NOTE.

At the College of Physicians and Surgeons, New York, the sub-department of Histology and Embryology, hitherto administered under the direction of the chair of Pathology, has been merged in the Department of Anatomy. This change was determined upon in the interests of a closer correlation of the work in these two branches of morphology, and in order to avoid the disastrous dissociation in the student's mind of the facts of gross and minute anatomy. A beginner is always more alive to the manner than to the matter of a study and is prone to accept an administrative form for an actual province of science; nor does he inevitably recover from this false impression ingrained at the outset of his career. In view of the increasing frequentation of our medical schools by men preparing themselves to become investigators and laboratory workers along special lines, their early orientation upon a broad basis of morphological study becomes of pressing importance. The recognition, therefore, of the essential unity of the study of structure, it is felt, ought not to be jeopardized for the sake of administrative convenience in the handling of material and instruments. In morphology it is as important as it is difficult to "see life steadily and see it whole." For the beginner the acquirement of an extensive basis is as important as is an intensive method for the investigator. The direction of the work is at least as significant as its momentum. Accordingly the course is planned to take advantage of the large collection of the Department of Anatomy to present the details of the finer structures hand in hand with demonstrations of gross anatomy; especially will use be made of the comparative series to illustrate by the adult conditions of lower forms the embryonic stages of the higher. It is, we believe, in the ontophyletic relations revealed in the comparison of evolution and recapitulation that the larger problems of morphology are conceived, and their educational value developed. For this purpose lectures will be given illustrated by means of an epidiascope in addition to the usual apparatus of dissections, models and charts.

The course begins with cytology. The general properties and

structure of living matter are considered from the standpoint of the protozoa. The structure of the cell is described, its processes of nutrition, movement, multiplication and necrobiosis, and combination with other cells to form individuals of a higher order. The study of the ovum affords a natural transition to the early stages of development of the embryo and the specialization of its cells to form simple tissue—histogenesis, followed by organogeny, the development of organs and apparatus which in turn is succeeded by the structure of the adult organs. Here it is essential that brief demonstrations of the gross anatomy of each organ should precede the microscopic study of its details. The course will conclude with the study of the central nervous system with especial emphasis laid upon its histo-architectonics interpreted upon the basis of the component theory.

Ten hours per week for thirty-two weeks have been allotted for this work. This time has been distributed as follows: lectures, three hours; laboratory work, six hours and conferences one hour weekly. Under the direction of Professor Huntington these courses will be given by H. von W. Schulte, M.D., Adjunct Professor of Anatomy, with A. H. Miller, M.A., and O. H. Strong, Ph.D., Instructors in Anatomy, and C. H. Smith, M.D., Assistant in Anatomy.

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OBSERVATIONS ON THE SINO-VENTRICULAR CONNECTING SYSTEM OF THE MAMMALIAN HEART.

BY

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WITH THREE FIGURES.

The literature of the so-called atrio-ventricular bundle of His has been so recently and so exhaustively reviewed by Tawara, Mönckeberg and others that it seems unnecessary at this time to do more than give a very brief survey of the history of the so-called bundle, reviewing somewhat more in detail the work of a few writers who have investigated the aspects of the subject with which my own work has especially dealt.

In 1845, as is well known, Purkinje first called attention to the presence in the subendocardial layer of the sheep's heart of a network of gray, flat, mucoid fibers, probably muscular in nature, partly on the papillary muscle, partly on other fibrous bundles and partly bridging folds and clefts in the heart wall. These fibers, which have always been known as Purkinje's fibers, were described by numerous writers in the half century following Purkinje's observations and they were noted, not only in the sheep heart, but also in that of pig, calf, goat, horse, dog, cat, rat, mouse, goose, hen, dove, and even in the human heart in the newborn infant by Henle and as late as 15 years old by Gegenbaur. They were usually found subendocardial, but were described also in the myocardium and by Hoffman in the pericardium.

In 1893, His, Jr., in mouse, dog and man discovered a bundle of muscle fibers arising in the posterior wall of the right auricle near the auricular septum in the auriculo-ventricular furrow, running along the upper edge of the ventricular septum musculature forward and dividing into a right and left branch which extend down into the ventricular septum and soon end by fusing with the ventricular muscle, thus connecting the auricular and ven-

tricular musculature. In 1904, this observation was confirmed by Retzer, who saw the bundle in cat, rabbit and rat, as well as in dog and man. He found the course varying slightly, but always connected with auricular muscle and merging into the ventricular at a short but variable distance from the point of division of the bundle. He estimates that in the human adult the bundle is about 18 mm. long, 2.5 mm. wide and 1.5 mm. thick. In 1906, Tawara made the most important contribution to our knowledge of this connecting muscular link between auricle and ventricle when he showed not only the presence of the bundle in every one of a large number of species of mammalia investigated, these including human embryo, child and adult, but also showed that the bundle ended, not as previously thought, by fusing immediately with the ventricular muscle, but by branching and spreading out into a complicated system of terminal fibers throughout the entire lower portion of the ventricles, these being the well known Purkinje fibers; that the bundle recognized by His and Retzer and the Purkinje fibers were but parts of a great complicated system of muscular fibers connecting auricle and ventricle. His results were confirmed in all important points by Keith and Flack in 1906, by Retzer, Fahr and Mönckeberg in 1908. Retzer showed that the system developed in the pig from the sinus which originates in the right and left venous valves and grows down in crescent-shaped lamellæ into the lumen of the right atrium. The left venous valve attaches itself to the atrial septum, the right divides into the Eustachian and Thebesian valves. The sinus fibers then grow down through the septum intermedium to the right and left sides of the interventricular septum where they become the highly differentiated structures—the Purkinje fibers. He suggests the term sino-ventricular conducting system, which is divided into the sino-ventricular bundle and the Purkinje fibers. In 1907, Fahr published a communication in which he confirmed Tawara's findings in the sheep heart but not in the human heart, in which he stated that the right and left limbs ended without branching, both in the embryo and in the adult, thus confirming the earlier findings of His and Retzer. However, in 1908, he modified his views, bringing them more in accord with the findings of Tawara. In this last work he reconstructed a portion of the interventricular septum with the bundle fibers of a three-year-old child. His model shows the left limb branching and sending twigs toward papillary muscles and growing down toward apex of heart and losing itself in the trabecular network. The right limb, however, he still represents as unbranched. In a twelve-year-old child however he finds slight but not extensive branching of the right limb also, but explains the difference between his findings and those of Tawara as due to a possible individual variation. Fahr was unable to recognize the bundle earlier than in a 16 cm. embryo and could see no branching of the bundle until later than this. Mönckeberg however (1908) traced the bundle and its two main limbs clearly in a 7.5 cm. human embryo and in a 16.5 cm. human embryo notes histologic differences between the bundle fibers and those of heart muscle and also notes the division of the left limb into several branches which he could trace through the trabeculæ to the papillary muscles. The right limb, however, showed no

branching in this series. According to Mönckeberg's investigations, this conducting system is found constantly in the human embryo from 7.5 cm. on. It varies slightly in its course in the atrium and with respect to its relation to the left and right surfaces as it passes through the annulus fibrosus and later in its terminal branching. The development, therefore, proceeds from sinus region downward into ventricle and later into the complicated system of Purkinje fibers.

An especial interest has attached to the study of this sino-ventricular system (1) because of the importance assigned to it by physiological experimentation and (2) because of its relation to certain well known but little understood pathologic and clinical conditions. The heart physiologists were divided into two classes, the neurogenists and the myogenists, the former believing that the contraction and rhythm of the heart were due to nerve influence, while the latter ascribed them entirely to muscular action. The neurogenists based their theory (1) on the well known and generally accepted fact that nerve cells are the natural originators of all impulses and nerve fibers the natural conductors of such impulses; (2) on the generally accepted absence of all muscular connection between the auricles and ventricles, at least in the higher mammalia, by means of which impulses could be conducted. The myogenists, on the other hand, rested their case on the early contractility of the heart, before the development of nerve elements and on the contractility of the heart in certain invertebrate forms in which a nerve mechanism in the heart seemed to be entirely lacking. The absence of a muscular connection between auricles and ventricles was an important missing link, however, in their chain of reasoning, by which they attempted to show that the impulses began in the sinus region and from there were carried to all parts of the heart in regular sequence and rhythm, the entire mechanism being muscular. This missing link was supplied by the discovery of this small connecting bundle of muscle fibers and it was at once seized upon by the myogenists to complete the chain of evidence in support of their theory. Humblet and Hering, by cutting the bundle, showed a dissociation of the auricular and ventricular rhythms, while Erlanger, by clamping the bundle, was able to cause either a partial or complete heart block, gradual or sudden, and also to bring the heart back to normal by loosening the clamp. His brilliant results seemed to establish beyond cavil the function of the bundle as conductive and as co-ordinating the auricular and ventricular rhythm and the muscular nature of its action seemed proved by Retzer's statement that no nerve fibers were included in the clamp and also by the declaration of His that no nerves run in the bundle. However, the presence of nerves in the bundle has been demonstrated conclusively by Tawara and others and later admitted by Retzer.

Clinicians and pathologists had long been interested in a disease described by Stokes and Adams and known as Stokes-Adams disease, in which the cardiac manifestations were similar or identical to those caused by experimental cutting or clamping of the bundle. It was therefore assumed that a pathologic affection of the bundle was responsible for this clinical affection

and numerous pathologic hearts have been subjected to investigation with reference to the condition of this connecting bundle. Among the most noteworthy contributions to the literature along this line are those of Tawara, Aschoff, Fahr and Mönckeberg.

Soon after the publication of Tawara's monograph, at the suggestion of Dr. Huber, I undertook an investigation of the sino-ventricular connecting system, especially with reference to verifying by reconstructions Tawara's findings regarding the extent and complexity of the system and its connection with the Purkinje system of fibers. Later publications have perhaps diminished the necessity for such verification, but the growing importance of the subject and the growing interest in its embryology, morphology, physiology and pathology will justify the presentation of my results. My investigations have been carried on by careful gross dissections of the system in sheep, calf and man, by wax reconstructions in man, calf and lamb and by histologic study in man, dog, sheep, calf and cat after different methods of fixation and staining, including the structure of the fibers themselves and of the connective and elastic tissue surrounding them, and the nerve distribution and supply.

My first model, shown in Fig. 1, represents the upper portion of the bundle in the adult human heart reconstructed by the Born plate method as modified by Mrs. Gage, paraffined absorbent paper of the required thickness being used instead of wax plates. The model is 25 times the size of the bundle and is reduced in the figure to about one-tenth the size of the model. The posterior extremity of the main trunk of the model represents the anterior portion of the Knoten, which will be described later, the remainder of the Knoten and its posterior extensions, where the outlines were less clear because of fusions with the auricular muscle, not being represented in the model. The actual length of the undivided trunk of the bundle, so far as shown in the model was 11 mm., the diameter varying considerably, being 1.6 mm., 2.8 mm. and 4.4 mm. in different parts. The division into two limbs taken place, as is usual, near the point of union of the posterior and median aortic valve flaps and at the upper extremity of the ventricular muscular septum, so that the right and left limbs begin as subendocardial strands, separated by the

narrow cone of ventricular muscle which is usually found at this place in the human heart. The left limb is broad and thin, broadening more and more as it passes downward following the curve of the septal wall and always subendocardial. It divides at a distance of 21.2 mm. below the point of bifurcation of the main bundle into

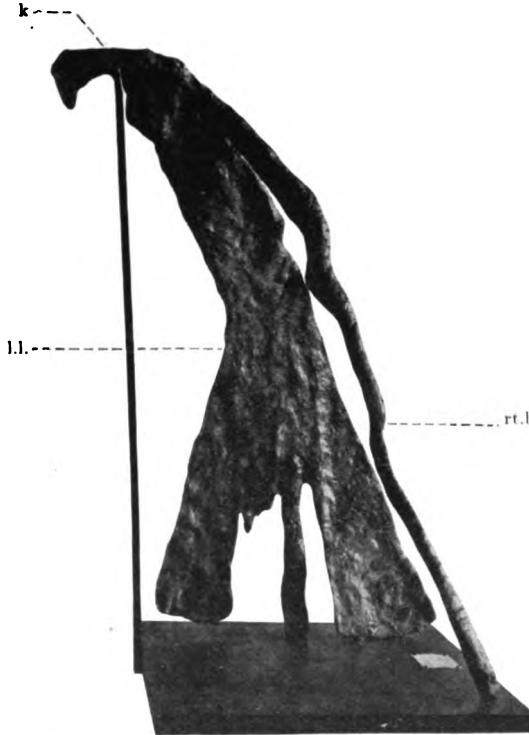


FIG. 1. Wax plate model of human sino-ventricular bundle 25 times magnified, reduced in figure to one-tenth size of model. k is Knoten; rt.l., the slender right limb; l.l., the broad left limb with first branching, into ant., post., and median branches.

three branches, the anterior and posterior branches being broad, while the mesial branch is much slenderer. These all continue subendocardial to the end of my series of sections and hence to the end of the model. The right limb is much smaller than the left and almost cylindrical, varying in diameter from .8 mm. to 1.6 mm. It is at first subendocardial, but, as the septum thickens, this limb

becomes surrounded by septum musculature and passes at first downward and forward and but little outward deep in the septum musculature for a distance of about 25 mm. It then turns sharply outward and its course is then downward and outward and but little forward for a distance of about 10 mm., when it reaches the endocardium. Here my series ends, near the point where the moderator band, or as Retzer more appropriately terms it, the trabecula supraventricularis, leaves the septum and carries the right limb of the bundle with a large mass of septum musculature to the anterior right papilla. The model represented in Fig. 2 represents the upper portion of the bundle in the lamb's heart 50 times magnified, but it is reduced in the figure to about one-twelfth the size of the model. It was made by the Born wax plate method and begins in the Knoten. Posterior to this point, the connection with the auricular muscle was so close and the outlines of the bundle so poorly marked on the auricular side that it was difficult to outline it with sufficient accuracy for reconstruction. The Knoten was from 1 to 1.5 mm. in diameter and 4 mm. long. At the neck where it passed through the annulus fibro-cartilagineus, it changed rather abruptly to a diameter of from .3 to .4 mm., enlarging again somewhat in the ventricular portion of the bundle. The narrowed neck portion was about 1 mm. in length and the bundle then extended downward and forward in the muscular interventricular septum about 4.6 mm., before it divided into the right and left limbs. The left limb then extended directly downward and outward to the endocardium on the left side of the septum, a distance of 3.4 mm., where it divided into two branches, an anterior and a posterior, the latter showing a small median branch near its beginning. These remain subendocardial to the end of the model. The unbranched subendocardial portion of the left limb was from 1.4 to 1.8 mm. in length and from .1 to .2 mm. in thickness. The right limb passes downward and forward and outward, a distance of 5 mm., until it reaches the endocardium where the series of sections ended. The right limb measures from .8 to 1.2 mm. in width and from .4 to .6 mm. in thickness, so that it approaches more nearly to the cylindrical form. The further course of the right and left limbs and their branches will be discussed further a little later

in this paper. These two models show the course of the main trunk of the bundle, the Knoten and the upper portion of the right and left limbs to be very much as had been represented by His, Retzer and Tawara. The block of human heart tissue serially sectioned for the model was something over 35 mm. in length and I realized at this time that a reconstruction of the sino-ventricular bundle with its terminal expansions would require serial sections of the entire ventricle with a portion of the auricle; that these sections would need

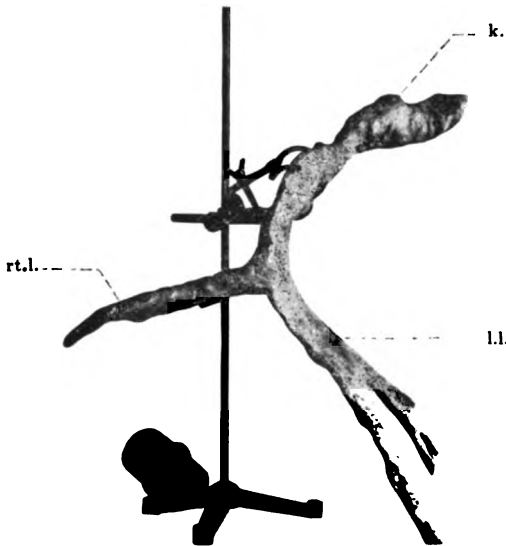


FIG. 2. Wax plate model of lamb's sino-ventricular bundle. k is the Knoten with main bundle. rt.l. is the upper portion of right limb, and l.l. the left limb with upper portion of branches.

to be relatively thin and to be magnified from 100 to 400 times in order to bring out the fine terminal ramifications of the bundle with any accuracy. Unwillingly recognizing the practical and economic difficulty and even impossibility of such a task in the larger hearts, I attempted to dissect out the bundle with its terminal ramifications and found that by the constant aid of a hand lens and the frequent aid of the microscope, the sino-ventricular system could be followed, not only in its subendocardial course, but also for some distance into the muscle, while it was comparatively easy to dissect out the main

limbs and to trace them back to the trunk and Knoten and to the beginning in the sinus region. Still desiring to make graphic as accurate a representation as possible of this entire connecting system, I conceived the idea of making a reconstruction from such a dissection. With the patient and skillful aid of Miss Gertrude Welton, one of my students, the model represented in Fig. 3 was constructed in the following manner. Choosing a young beef heart in which the differentiation between heart muscle and that of the sino-ventricular system was well marked, the entire heart was fixed in Kaiserling's solution, the ventricles being first filled with the solution and the heart then suspended in the Kaiserling's solution, in order to prevent the distortion which frequently follows fixation in the ordinary way. The apex and outer wall of the left ventricle were then removed, leaving the anterior and posterior left papillæ in situ. The right ventricle was then opened carefully from above down posteriorly, without cutting the trabecula supraventricularis or destroying any of the apical connections between septum and outer wall. Starting with the easily seen left limb, removing the superficial layer of the endocardium, the dissection of the main bundle, Knoten and upper portion of the main limbs was relatively easy. The dissection of the terminal ramifications was then carried on with needles, constantly using the hand lens and, when in doubt, the microscope, until the entire system was exposed, so far as it was possible to differentiate it from the cardiac muscle. Then lengths, diameters and angles were carefully measured at every point, the measurements multiplied by ten, a wire skeleton was constructed and covered with wax, all angles and measurements being retained, as nearly as possible in the same proportion. Hence the model represents a ten-fold magnified sino-ventricular system of the beef heart, as accurately as a hand lens and gross dissection can show it. The connective tissue sheath was not always entirely removed, since that would often mean the complete disintegration of the bundle; hence the threads and especially the nodes represent these portions of the system with the most closely adherent connective tissue. As seen in this model represented in Fig. 3, which should be viewed through a stereoscope, the main bundle begins in the region of the coronary sinus by the union

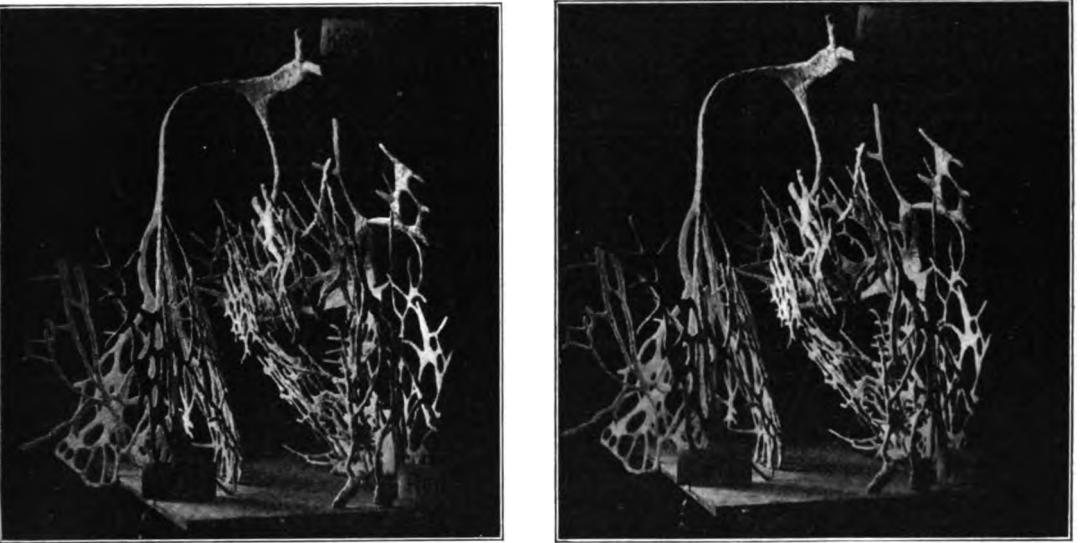


FIG. 3. Stereoscope photograph of model of sino-ventricular system in calf's heart. To be viewed through stereoscope.

of two portions, the origin of one of which seems to be lost in the mass of fat, connective tissue, nerve fibers and ganglion cells, which are found in the region of the sinus, while the other can be traced upward for a short distance and is then lost or merged in the auricular muscle. Some connections with the auricular muscle at the sides and upper part of the Knoten are not represented. The actual length of the bundle to the point of division was 33 mm. The point of division lay at the upper margin of the interventricular septum as in the human and not deep in the septum musculature as in the sheep heart. The left limb was therefore subendocardial from the beginning, while the right limb lay buried under about 1 mm. of muscle. After passing about 38 mm. almost vertically downward from the point of division, the left limb divides into two main branches, an anterior and a posterior. The anterior and posterior branches pass each into a fibro-muscular strand or false tendon, these crossing the ventricular cavity to the anterior and posterior papillæ. About 2 mm. beyond the point of division, the posterior branch gives off two long slender branches to the septal wall, which anastomose

with branches from a septal branch of the anterior division to form a septal plexus. The posterior division proceeds downward and backward about 20 mm. when it gives off an internal branch, which soon forms a characteristic node, from which five branches are given off, three to the septal wall and two to the inner side of the posterior papilla. About 12 mm. further down, the main posterior branch reaches the anterior side of the posterior papilla, where it divides into two branches, each of which again subdivides, the resulting branchings frequently fusing with each other or with strands from other divisions into characteristic node-like forms, which again break up, thus forming a complicated network, surrounding and penetrating the papilla, sometimes on the surface and often deep in the muscle. One long slender branch runs around the inner side of the papilla and could be traced nearly to the apex of the papilla, most of it buried deep in the papillary muscle. Occasional branches are given off from the papillary network to join the septal network, which will be more fully described later. The papillary branches could be traced as independent strands nearly to the apex of the papilla, where they were lost or became continuous with the papillary muscle. The anterior papillary division, about 3 mm. below the point of its formation, gives off a large septal branch, while the remainder passes downward and forward without further branching to the anterior papilla, where it divides into three main branches, one of which is slender and passes around the septal side of the papilla near its apex; the other two are of nearly equal size, the one external and the other internal. Both subdivide a number of times, the resulting twigs anastomosing with each other at intervals to form the characteristic node-like forms which were before described, in which the component fibers lose their identity in a mass of connective tissue, containing large numbers of the so-called Purkinje fibers. This then breaks up again into separate independent fibers, some of which again enter into a node and again divide, the whole forming a plexus-like arrangement over the entire posterior surface of the anterior papilla. In the heart from which this model was constructed, the outer wall of the left ventricle was removed for convenience of dissection, so that the network which we know to have

been present on this wall and to have been derived from branches of the papillary divisions, is not shown in the model. The septal wall of the left ventricle both between the papillæ and where it curves around behind the papillæ is covered by a network of Purkinje fibers, similar to the network described on the papillæ and formed of the anastomosing subdivisions of septal branches of the anterior and posterior divisions of the main limb, which have already been described. These form the node-like forms described, which, with their connecting strands make up the network. Occasional small branches pass back from the anterior and posterior papillary plexuses to the septum and join with the septal branches to form the septal plexus. The plexus described covers well the septal surface to the level of the branching of the main left limb and even sends some fine filaments higher on the septal surface. The right limb is narrower and more nearly cylindrical than the left and approaches the endocardium slowly. It runs at first downward and outward and a little forward and then downward and forward and a little outward. After an unbranched course of about 42 mm. in the septal wall, it enters the moderator band or trabecula supraventricularis, which in this heart was about 23 mm. long, making the total length of the unbranched right limb 65 mm. I was unable to find any branches given off from this limb before it reached the anterior papilla, which it entered on its anterior surface about 28 mm. below its apex. Here it bifurcated, one branch passing forward to the outer wall of the right ventricle, while the other passed backward on the papilla. Both of these branches break up into a large number of smaller branches, which form nodes and redivide and form a plexus similar in all respects to that described on the left side. Some of these branches could be traced upward on the exterior wall nearly to the base of the ventricle, some running quite deeply in the ventricular muscle, but most of them in the endocardium just under its superficial layer. One branch passed around the papilla on its septal side nearly to its apex, while another passed on its peripheral side, the two nearly encircling the papilla near its apex. From the plexus described in the outer wall of the right ventricle and the anterior papilla on that wall, three main branches pass back to the right surface of the

septum and the broad flat posterior papilla which is closely attached to the septum and presents only a short blunt head projecting forward and upward from its septal attachment. These branches reach the posterior part of the septal wall, redivide, form nodes and again break up, so that the entire right surface of the septum to about 20 mm. from the base is covered with an intricate network of these terminal branches of the sino-ventricular system. While this model represents the ramifications and distribution of the system in only one heart, careful gross dissections of other calf hearts and also of human and sheep hearts have shown beyond question that the distribution shown in the model may be regarded as typical. The main bundle may be longer or shorter, may be a little more to the left or right of the position shown in model and in the sheep, as before stated, passes down some distance into the interventricular septum before dividing. In all cases investigated, however, the bundle divided into two limbs, the right passing unbranched to the anterior papilla, where it divided into either two or three branches, from which a network similar to that shown in the model spread out over the papilla, the outer wall and the septum, while the left limb divided into either two or three branches, the anterior and posterior passing to the anterior and posterior papillæ and forming networks, while the median, if it exists, or if not, septal branches of the anterior and posterior divisions form a septal network. The general course was the same, but slight modifications were found, not only in the hearts of different species, but also in those of different individuals of the same species.

In the complicated course described and modeled, branches of the system often cross, not only narrow clefts between columnæ carneæ, but also the entire ventricular cavity by means of longer or shorter trabeculæ, which resemble connective tissue and are known as pseudo-tendinous threads. Tawara and Mönckeberg have made these threads the subject of exhaustive research, especially with reference to their abnormal course in the left ventricle of the human heart in various pathologic conditions. Tawara defines these abnormal tendon threads as "bundles of the atrio-ventricular system which have become loosened from the walls and pass freely through the ventricular cavity." Mönckeberg, however, after study of numerous pathologic

conditions, concludes that not all trabeculæ crossing the ventricular cavity between the septum and the papillæ carry branches of the atrio-ventricular bundle. He divides them into three main classes: A. Threads having no muscle at all, but consisting of connective tissue—true tendon threads. B. Threads carrying both myocardial fibers and fibers of the atrio-ventricular system. C. Threads carrying only fibers of the atrio-ventricular system with their connective tissue sheaths. In order to determine whether this classification in abnormal human hearts might apply also to normal animal hearts, I examined microscopically all threads, long and short, crossing the ventricular cavity in two beef hearts. Since the results seemed uniform, with very slight variations in the number and course of such threads, I will describe in detail the threads found in only one of these hearts.

A. From the upper portion of the septal wall in the neighborhood of the valve insertion, three or four fine threads passed to the papillæ, being inserted in or near the apices of the papillæ. These threads consisted of connective tissue only and contained no muscle fibers, so that they may be regarded as belonging to Mönckeberg's Class A.

B. In the left ventricle, the following threads were found:

1. Between middle or lower part of posterior left papilla and septum below valve level.

a. Large strand from about 24 mm. below septum membranaceum to about 8 mm. below apex of papilla, with two fine subbranches back to septum.

b. 5 mm. lower, a smaller strand with two subbranches, one to septum and one to lower trabecula.

c. Short slender thread 7 mm. lower, with one subbranch to septum and one connecting with thread No. 2.

2. Between middle and lower part of anterior left papilla and septum below valve level.

a. Large strand from 30 mm. below septum membranaceum to 15 mm. below apex of papilla. No subbranches.

b. 4 mm. lower, smaller thread with two subbranches to septum.

c. Small thread 4 mm. lower with one subbranch.

All of these threads were examined microscopically and all were found to contain connective tissue, blood vessels and nerves and larger or smaller fibers belonging to the sino-ventricular system. All except two very fine ones contained also some myocardial fibers.

3. On the right side, the main moderator band or trabecula supra-ventricularis was the only connection between the anterior papilla and the middle part of the septal wall and this had no branches. The posterior right papilla is a broad flat papilla closely attached to the septum and between it and the outer wall of the ventricle two main strands could be seen, each of which had several subbranches. All of these showed both myocardial fibers and fibers of the sino-ventricular system, as well as numerous nerves and blood vessels and connective tissue.

C. The two threads found on the left side, which contained no myocardial fibers, but only sino-ventricular fibers, connective tissue and nerves and blood vessels.

From the limited number of investigations I have thus far been able to make on these threads, therefore, I would conclude that in the heart of the calf at least, as Mönckeberg has shown in the human heart, true tendon threads are found connecting the upper part of the septum with the apices of the papillæ; that below the branching of the main limbs of the bundle, all the pseudo-tendinous threads crossing the ventricular cavity carry branches of the sino-ventricular system.

I find also that the great majority of them may be regarded as belonging to his Class B, carrying both myocardial and sino-ventricular fibers, while only one or two very fine, short ones belong to Class C, carrying no myocardial fibers. I also find that all the threads of Classes B and C carry, in addition to the muscle fibers, small blood vessels and bundles of nerve fibers, the latter running in the connective tissue around the sino-ventricular branch and often sending finer nerve bundles between its individual fibers. Retzer regards the so-called false tendons in the pig as always bridges for the conductive system, this including both Purkinje fibers and nerve fibers.

HISTOLOGY OF SINO-VENTRICULAR SYSTEM.

The earlier writers on the histology of the Purkinje fibers were divided into two great classes, (a) those who, with Purkinje, described two kinds of elements in the fibers, a network of cross-striped fibers resembling heart muscle, in the meshes of which were imbedded peculiar, clear mucoid cells, containing nuclei; b, those who believed that the Purkinje fibers consisted of short broad cells, whose center was clear and mucoid in character and contained from one to several nucleoid bodies, while the periphery showed cross-striped fibrils similar to those in heart muscle, thus having only one kind of element. Tawara, however, in his monograph, has described in detail the histology of the entire sino-ventricular system in sheep, dog, and man and his description with few modifications has been followed by all later writers. In all forms described, he divides the atrioventricular system structurally into two main portions, the auricular and the ventricular, each of which is subdivided into two parts: the auricular into the trunk and the Knoten, the ventricular into the upper undivided part and the terminal expansions or Purkinje fibers, the differences in structure being most marked in the sheep and least marked in the human heart, the dog being intermediate in the differentiation of this system. The Knoten in the sheep is described as a complicated network of small irregular fibers, which change as the bundle passes through the annulus fibro-cartilagineus, into large clear fibers, with peripheral fibrillation and central nuclei. This type becomes more pronounced when the limbs reach the endocardium and spread out in the terminal ramifications, which are known as Purkinje fibers and which later fuse with the myocardial fibers. Tawara describes the fibers of the main limbs and terminal expansions in the sheep heart as consisting of broad, short, irregular, polymorphous cells, two or three or more of which side by side are united to form cell strands, which at intervals anastomose with other cell strands forming often node-like structures, the whole appearing as a complicated network in the meshes of which are found connective tissue, fat, blood vessels and nerves. The fibril bundles are mostly at periphery of the cells and run uninterruptedly from one cell to another in the cell strand. In the terminal expansions, the clear centers are more pronounced and the meshes of the network longer and narrower. In spite of the continuity of the fibril bundles, Tawara regards the strands as consisting of separate and independent cells connected by intercellular fibrils comparable to those in the epithelial cells of the epidermis. In dog and man, he finds the auricular portion of the system similar to that in the sheep, while the ventricular portion is less sharply differentiated by reason of the more extensive development of the fibrillar structures. In the new-born dog, the fibers of the bundle consist of short broad cells with clear nucleated centers and fibrillated borders, very similar to those in the sheep, while in the adult dog he finds "sarco-plasmic territories" with distinct limiting zones, so that in the dog also he regards the Purkinje fibers as consisting of cells with connecting fibrils, the fibrillar structures being more developed and more uniformly scattered throughout the cells than in the sheep. In the human heart, the Purkinje fibers are even less clearly differentiated from the myocar-

dium than in the dog's heart, but he regards them as cellular rather than syncytial because of the presence of cross lines which are arched or wave-like, rather than step-like as in the myocardium and completely divide the fiber, between two nucleated areas; he also finds some of the fibril bundles stopping at the cross lines while others pass through. The careful and detailed description given by Tawara has been accepted by other authors with very little modification. Retzer denies the existence of a Knoten in the pig's heart, stating that he finds the network-like structure ascribed to it by Tawara throughout both the auricular and ventricular portions of the system. Mönckeberg, in his excellent monograph on the atrio-ventricular system in the human heart, questions Tawara's view that the cross lines seen in the Purkinje fibers of the human heart represent cell outlines, although he admits the presence of separate independent short polymorphous cells with clear nucleated centers and narrow peripheral fibrillar zone in the sino-ventricular system of a 16.5 cm. human embryo. He states that the development of fibrils results in the formation of solid star-like or fusiform structures with anastomosing processes forming a network, with vesicular cells forming the meshes. Later the solid portions unite into tube-like fibers with occasional connecting branches, this process being carried further in the limbs than in the Knoten, where the network structure is preserved. An interesting communication by Aschoff reporting the work of his student Nagayo, calls attention to the glycogen content of the sino-ventricular system. In the beef, calf and sheep heart, he finds glycogen constantly present and characteristically distributed, either diffusely scattered in the interfibrillar portion or as numerous large granules in the perinuclear sarcoplasmic area, except in the Knoten, where there is but little. In the goat also it is constantly present, but mostly diffuse. In the pig, corresponding with Retzer's finding of the extension of the Knoten structure into the ventricle, he finds very little glycogen and almost limited to the terminal expansions. In the human bundle, the results were variable; thirty hearts were investigated, of which three showed distinct glycogen content, nine very small amount of glycogen, and eighteen almost none. The dog's heart with reference to the glycogen content of the sino-ventricular system, resembles the human heart, if we regard the large amount of glycogen as the normal condition. Mönckeberg also investigated the glycogen content of the sino-ventricular system in the human heart at different ages and under different pathologic conditions and, like Aschoff, finds it variable, a fact which he ascribes to pathologic conditions or to poor condition of tissues. He concludes that myocardial fibers are always glycogen-free in post-uterine life, while in the Purkinje fibers it is constantly and characteristically present, though diminished in atrophic and cachectic conditions and that glycogen stains may be used in properly fixed hearts as a means of differentiation between Purkinje fibers and myocardial fibers. The main points of variance then are (1) as to the presence and histologic differentiation of such an auricular structure as is designated by Tawara as the Knoten; (2) as to whether the ventricular portion of the system and especially the Purkinje fibers are syncytial or cellular in structure.

In my investigation of the histology of the sino-ventricular system I have studied the hearts of sheep, both young and adult, of calf, of dog, including a 6 cm. embryo, a 3-day old puppy and an old dog, of cat and of man. I have used the ordinary hematoxylin and eosin and hematoxylin and Van Gieson stains, also the Schultze chrom-hematoxylin, the Heidenhain iron hematoxylin, the silver, the Mallory connective tissue stain, the Weigert elastic tissue stain, and also the methods recommended by Heidenhain for the study of heart muscle. In all these types the most constant and typical structure found was the network in the auricular portion of the system designated by Tawara as the Knoten. This in all cases consisted of an intricate network of fibers, which varied greatly in size, but the average size of which was much less than that of the auricular muscle or of the rest of the sino-ventricular system; the nuclei are smaller and more numerous than in the auricular muscle. The anastomosis of the fibers takes place, not by simple fusion of two uniting branches, as is usual in heart muscle, but by the formation of nodes or star-like forms, into which two or three or more fibers become merged and from which a variable number of fibers emerge. In the node, the fibers completely lose their identity, fibrils from the different fibers commingling confusedly. Surrounding the Knoten and in the meshes of its network are found connective tissue, blood vessels and many nerve fiber bundles, especially in the lamb and calf heart, with numerous ganglion cells in the calf's heart and a few were seen in the sheep's heart. In the sino-ventricular system of the sheep and calf, this small-fibered network changes rather abruptly, shortly before the bundle passes through the annulus fibro-cartilagineus into a large-fibered network, the change beginning in the central portion of the bundle. The ventricular portion of the sino-ventricular system is markedly different in the different species examined. In the sheep and calf, where the fibers are most typical and most clearly differentiated from the myocardial fibers, the fibers are much larger than the myocardial fibers, with fewer fibrils and much more sarcoplasm. The fibrils are grouped into larger and smaller bundles, which run partly in the direction of the fiber and partly cross it in devious directions, forming a network which

encloses certain clearer areas in which are found one or several nuclei. Tawara regards these as independent cells joined together to form cell strands, but even in the sheep, in which the apparent cell outlines are most distinct, the fiber appears to me as a syncytium, a continuous mass of sarcoplasm, through which run the bundles of cross-striped fibrils in different directions, dividing up the sarcoplasmic mass into clearer non-fibrillar areas, containing one or several nuclei and three to six of which make up the transverse diameter of most of the fibers. The fiber bundles themselves anastomose at intervals, forming a network in the meshes of which are found connective tissue having many more elastic fibers than are found between the myocardial fibers, blood vessels and nerves. These rarely penetrate the fiber strand and then only a short distance. In the calf, ganglion cells were found in these meshes throughout the entire distribution of the system, but I have been unable to duplicate this finding in the hearts of other species examined. My reasons for believing that the fibers of the sino-ventricular system are syncytial in character are (1) the fibrils and fibril bundles pass uninterruptedly through the fiber in different directions, forming a more complicated fibrillar network throughout the fiber than could be accounted for by any other hypothesis than that the fiber is the unit of the system; (2) I have been unable to find white or elastic connective tissue fibers penetrating the fiber, or dividing it, except a few peripheral strands which are easily explained as following the irregular contour of the fiber strand. Also no blood vessels or nerves seem to penetrate the fiber bundle; (3) I have occasionally seen clefts such as were mentioned by Tawara, but believe them to be due to shrinkage of the sarcoplasm during fixation. The cell-like forms or sarcoplasmic territories are very variable in form and size and separated simply by strands of cross-striped fibrils. In the terminal expansions of the system, the fibers, if cut longitudinally, appear oblong and occasional cross bands are seen, not unlike those in the myocardium, but either straight or slightly curved or arched, rarely step-like as in the myocardium. In dog, cat and man, the fibers of the ventricular portion of the sino-ventricular system more nearly resemble the myocardial fibers, being differentiated from them by being

broader and paler and less fibrillar and more vacuolated, large, clear nucleus-containing areas resembling those in the sheep being not infrequent. The nuclei are smaller and less frequent than in the myocardium, although occasionally two or more are seen in a single sarcoplasmic territory. The cross lines are distinct and often cross the entire fiber, but may occur at frequent intervals, the short space between them being non-nucleated, or they may be widely separated, several nucleated spaces occurring between two such bands; this finding was noted also by Mönckeberg. The fibers are very variable in size and nodal points showing a commingling of fibrils from different fibers are frequent. The appearance varies somewhat with the direction of the section, a section tangential to the endocardial surface showing much broader fibers with larger perinuclear areas than one vertical to the surface, showing that the fibers are broader than they are deep, the broader dimension lying parallel to the endocardial surface. Connective tissue and especially elastic fibers are much more abundant than in the myocardium. In the 3 cm. dog embryo and also in the 3-day old puppy the fibers appeared as independent cells, sharply outlined by blue lines in the Mallory stain, an outlining which was never brought out in the adult condition. Hence my findings in the embryo and newborn agree with those of Tawara and Mönckeberg as to the fact that Purkinje fibers are composed of single short clear cells, but in later life, at least in man, dog, and cat, and probably also in sheep and calf, the fiber bundle seems to me syncytial.

Transitions from the fibers of the sino-ventricular system to the myocardial fibers are rarely seen in my sections; this is explained by the fact that the transition is very gradual, so that only rarely would a section follow a fiber through the entire transition from a typical Purkinje fiber to a typical myocardial fiber. Beginnings and endings of the transition are frequently seen, and in one or two instances I have been able to trace the entire process. It is impossible to say from my sections, however, whether all the fibers of the sino-ventricular system end by fusion with the myocardial fibers or not.

Nerves. Tawara states that he finds the sino-ventricular system of the calf accompanied throughout by numerous large nerve bundles, which are intimately associated with the muscle bundles and even in the ventricular portion of the system contain ganglion cells. He also finds small nerve bundles in the sheep heart, but no noteworthy nerve bundles in man, dog, or cat, though he admits that quite fine nerve bundles may accompany the system in all species of animals. Mönckeberg states that in the human sino-ventricular system he finds no nerve elements or forms resembling such, though he used many special methods for their demonstration. Wilson, after examining the atrio-ventricular bundle in calf, sheep and pig, states that he finds in it, in addition to the special form of muscle fiber, an important and intricate nerve pathway, consisting of:—

(1) Numerous ganglion cells, mono-polar, bi-polar and multi-polar, whose processes pass either to other ganglion cells in the bundle, to the muscle fibers of the bundle, or through the bundle so far as examined.

(2) Abundant nerve fibers running through the bundle in strands and either ending in ganglion cells in the bundle, or in the muscle plexus, or passing through the bundle, so far as examined.

(3) An intricate plexus of varicose fibrils around and in close relation to muscle fibers of the bundle.

(4) An abundant vascular supply with well-marked vaso-motor nerves and sensory endings.

Retzer, on account of the presence and close relation of nerve fibers to bundle fibers in pig's heart, regards the system as a neuromuscular end-organ, a conclusion with which Wilson does not agree, since he finds the essential anatomical structure of a neuro-muscular spindle,—shape, lymph spaces, lamellar capsule, as well as nerve endings,—lacking in the sino-ventricular system, while ganglion cells are present in the system and absent in the neuromuscular spindles.

In the calf's heart, the nerve bundles are so large and prominent, not only in the Knoten, but also throughout the distribution of the sino-ventricular system, that they are readily seen in preparations stained by ordinary methods, and it would be impossible in this heart to question the prominent part which nerves and ganglion cells play in the structure and probably in the function of the sino-ventricular system. They are not only in the connective tissue sheath, but smaller bundles run between the fibers and appear to stand in more or less intimate relation to the fibers of the system. In the hearts of young lambs, and to a less marked extent also in those of older sheep, the nerve fiber bundles also follow the entire distribution of the system, although few ganglion cells could be seen in it, after the bundle passed through the annulus fibro-cartilagineus. In the

hearts of dogs, cats and men, larger nerve bundles were more rarely seen, and then only in the connective tissue sheaths of the system, and very small fiber bundles or single fibers only are seen between the single fibers and it is usually difficult to distinguish any nerve fibers between the muscle fibers of the terminal expansions. I have studied the nerve distribution in lambs' hearts with the intravital methylene-blue method and found larger nerve bundles in the sheath, breaking up into smaller bundles and finally into a network of single fibers, which appeared to end on the muscle fibers of the bundle, although nerve terminations were not satisfactorily demonstrated. It would appear that the nerve supply is independent of that in the immediately surrounding myocardium, since in some of my preparations very few of the nerve fibers surrounding the myocardial fibers were stained, while the nerve fibers of the sino-ventricular system were well stained throughout its entire distribution in the ventricular as well as in the auricular portion. Ganglion cells also were found, so that my findings corroborate those of Wilson in every particular. The question of the nerve and blood vessel distribution, however, I desire to leave for further investigation, the results of which will be published with those of investigations on other phases of the subject in a later communication.

Regarding the function of the sino-ventricular system, my investigations have had little to do. That it has a function independent of that of the myocardium seems assured from the constancy of its presence in all species studied, the relative constancy of its structure and distribution, the probable independence of its blood and nerve supply, the relatively constant and typical glycogen content, as shown by Aschoff and Mönckeberg, and its independent pathology, as shown by Tawara, Mönckeberg, Fahr and others. That its function is conductive, or at least coordinative, seems probable, both from physiologic experimentation and from pathologic study. Whether it may also originate impulses and thus account for the independent ventricular rhythm established after severance of the connection between auricle and ventricle, and whether its function is muscular, nervous or neuro-muscular, must be left for further study and experimentation. Because of the large number of nerves and their intimate

relation to the muscles, at least in some of the species studied, the neuro-muscular hypothesis seems to me the most probable and it may be possible that it is called into action by the distension of the ventricles and the stretching of the endocardium.

In conclusion I desire to thank Dr. Huber for suggesting the subject of this investigation and for the kindly interest he has shown in its progress; also I wish to express my appreciation of the skill and patience with which Miss Gertrude Welton aided me in the construction of the model; I am grateful also to Drs. Novy and Streeter for their aid in photographing the models.

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ON THE DEVELOPMENT OF THE AORTAE, CARDINAL
AND UMBILICAL VEINS, AND THE OTHER BLOOD
VESSELS OF VERTEBRATE EMBRYOS
FROM CAPILLARIES.¹

BY

HERBERT M. EVANS.

From the Anatomical Laboratory of the Johns Hopkins University.

WITH TWENTY-ONE FIGURES.

In explanation of the somewhat comprehensive title of this report, I would say that I have omitted entirely, for the present at least, the development of the heart, first arch and cephalic aortæ. But, on the other hand, the injections which I shall describe speak with great clearness on the primitive form and development of all that portion of the aorta below the omphalo-mesenteric arteries, of the entire upper portions of the anterior cardinal veins, and quite fully, of the posterior cardinal and umbilical veins. In addition to these primary trunks, I have explored other branches of the vascular tree in embryos of different ages and in various portions of the body and find everywhere the same story.

The patient and thoroughgoing analysis of serial sections through vertebrate embryos has, in the last twenty years, given us a fairly accurate idea of the position, size, and relations of all the chief vascular trunks present in successive stages. But such knowledge, even though complete, can tell us little or nothing about the method of development of the vascular system. When a large trunk is described as having extended to a certain level in the body wall or on a viscus we have still no idea of how it reached its position. Many processes could be concerned.

¹Read at the Twenty-fourth Session of the Association of American Anatomists, December, 1908.

If the vessel in question was derived from neighboring vessels, and in some instances even this has been disputed, have we then to conceive of it as having grown out *as such* to its future territory? Certainly such a conception dominated the descriptive anatomy of a century ago and even to-day has not altogether lost its influence. Arteries are still described as dividing dichotomously and otherwise in accordance with the unconscious simile afforded by plant growth. To such an idea many of the vascular anomalies proved an utter enigma. Double vessels in place of the usual single one were disposed of by considering one vessel as the normal one and its brother as the interloper or "aberrant." It is easy to understand the curiosity with which anastomoses between strong and usually separate arterial channels were looked upon. Why indeed should vessels which had grown out to their destination, send communicating branches to their neighbors? Thus the surprise with which Hunter discovered the phenomenon of a collateral circulation. Such phenomena in the adult body are themselves splendid evidences for quite another conception of the development of the vascular system, a conception which was first partially expressed by the anatomist Aëby in his "*Der Bau des menschlichen Körpers*," in 1868. Aëby contributed a mere hypothesis, but it has only recently been recalled and can now be convincingly supported by actual studies on the early developing vessels.

Both arteries and veins, said Aëby, arise from netlike Anlagen; the veins retain this the more, whence the numerous venous anastomoses; the arteries hardly at all, whence their greater rarity here. He conceived of the whole question as one of functional adaptation. Not all the members of the vascular net are retained; the victors in the struggle are the trunks as we know them in the adult.

Such an illuminating conception explained adequately all vascular anomalies. From the preceding network, the persisting vessel could course in practically any direction and with practically any connections. Though Krause, who wrote the admirable section on the variation of the vascular system in Henle's *Anatomy*,² readily saw the advantages of Aëby's explanation and adopted it, the conception was not recalled in any form for many years.

²Henle, J. "*Handbuch der Gefässlehre des Menschen*," Braunschweig, 1876.

In the anatomy of the adult vascular system nothing approaching a netlike condition exists until we reach the capillary bed, where it forms a characteristic feature. Is it not indeed a capillary net, this primitive net postulated by Aeby?

The answer to this was given by the research of R. Thoma³ in 1893. In his attempt to solve the question of ancestry of arteries and veins Thoma selected the chick's yolk vessels where he soon observed stages so early that only a plexus of capillaries existed. Here no channels of the net were conspicuously larger or smaller than their neighbors, but from among them, in later stages, the chief vitelline arteries and veins are formed. Thoma's idea of how this transformation is brought about, his conception of the determining influence of the velocity of the circulation, is of the greatest interest, though it has not been adequately tested, nor does it concern us here. On anatomical grounds alone, however, it should be possible to establish clearly or disprove the more general statement that arteries and veins exist originally in the form of a capillary mesh. If this is a fact of general value, it will apply to the developing vascular system within the body of the embryo quite as well as to the extra-embryonic circulation which Thoma had studied. The work of three recent investigators has indicated that this is indeed the case. I refer to the papers of Müller, Rabl, and Sterzi. The latter observer has studied the vascularization of the spinal cord and some of his descriptions are splendid evidence of the capillary plexus ancestry of these vessels, though Sterzi himself has not realized their wider significance in this light. As I shall show later, the vessels of the cord and brain illustrate particularly well the method of origin and growth of the vascular system. The work of Müller and of Rabl has been referred to in a previous communication⁴ in which I also called attention to Curt Elze's emphatic criticism of their contention. Elze,⁵ in a research done chiefly in Hochstetter's laboratory, has

³Thoma, R. "Untersuchungen über die Histogenese und Histomechanik des Gefässsystems," 1893.

⁴Evans. "On an Instance of Two Subclavian Arteries to the Early Arm Bud of Man," *Anat. Record*, II, 9, Dec., 1908.

⁵Elze. "Beschreibung eines menschlichen Embryo," *Anat. Hefte*, Bd. 35, 1907.

seen fit to deny emphatically such an origin for the blood vessels. One were as justified, he says, in the absurdity of considering the aortic arches as arising from capillaries, and yet many of the injections in this series show exactly this origin for the arches.

Moreover, it has now been possible to show that the main vessels of the limbs, the subclavian and the sciatic arteries, are the single persisting channels of a distinct plexus of capillaries which springs directly from the lateral aortic wall opposite the earliest indication of the limb buds.⁶

Surely, however, the whole question can be put to the most convincing test possible if the primary vessels themselves, the aortæ and the cardinal veins, can be shown to be formed in this way. I have accordingly set to work to decide this question through injections of very young embryos. The injection method had already shown itself to be by far the most efficient way to demonstrate the form and entire extent of the vascular system in any area or organ. The methods employed in the injection of these minute vessels have already been indicated in a previous publication and a portion of the injected specimens shown at the last two annual meetings of this association, at New York, 1906, and at Chicago, 1907.

Chick embryos were selected for the study, not only for the convenience in securing and controlling material but also because the presence of early and easily accessible vitelline vessels furnishes a good portal of entry for the injection.

DEVELOPMENT OF THE LOWER AORTÆ.

In embryos of the chick and duck possessing from twelve to fifteen somites, the aortæ begin to be in free communication with the extra-embryonic vitelline capillary net near the most caudal of the series of somites. Here also the character of the aortæ becomes entirely changed. They are no longer the distinct and fairly straight tubes which they constitute in the upper portion of the body, but instead

⁶Evans. "On the Earliest Blood-vessels in the Anterior Limb Buds of Birds and their Relation to the Primary Subclavian Artery." *Am. Jour. Anat.*, IX, 2, May, 1909.

begin to be most irregular, connecting with the vitelline capillaries at as many points as would obtain in any capillary mesh and soon becoming resolved completely into the general extra-embryonic net from which they are entirely indistinguishable. In but a short distance, corresponding to the length of some five or six somites (were they present here), the vitelline capillaries no longer gain the median region of the embryo but surround the latter in a wide detour which always characteristically encircles the caudal extremity—the region of the primitive streak.

By the time the embryo possesses some twenty-four somites, the two aortæ extend entirely through it, fusing with the vitelline capillaries only when the caudal tip has been reached. In what manner were the lower aortæ developed?

A study of the intermediate stages in injected specimens makes it possible to give a very clear answer to this question.

By the stage of twenty somites marked changes have occurred from the earlier condition described. The aortæ no longer appear to terminate in the region from the twelfth somite on, but are continued as strong vessels to the level of the twentieth segment, the caudal limit formerly reached by the most medial portion of the extra-embryonic plexus. Evidently the plexus formerly here has given place to the stronger single channel, but it has also continued to grow caudally in the tissues of the embryo, for it now reaches a considerable distance further caudad, to a point corresponding in position with the future twenty-fifth somite. In other words, there has been a continuous caudad invasion of the embryo by a plexus continuous always laterally with the extra-embryonic or vitelline net.

FIG. 1.—Ventral view of the posterior part of an injected chick embryo of 17 somites, showing plexiform character of the aortæ opposite the 17th somite.

FIG. 2.—Ventral view of the posterior part of an injected chick embryo of 20 somites, showing an extension of the plexus out of which the aorta develops. The large nonvascular area surrounding the region of the primitive streak is here much reduced in extent.

FIG. 3.—Ventral view of the posterior part of an injected chick embryo of 23 somites, showing the completion of the down growth of the capillary plexus out of which the aortæ are formed.

BLOOD VESSELS OF VERTEBRATE EMBRYOS.

HERBERT M. EVANS.

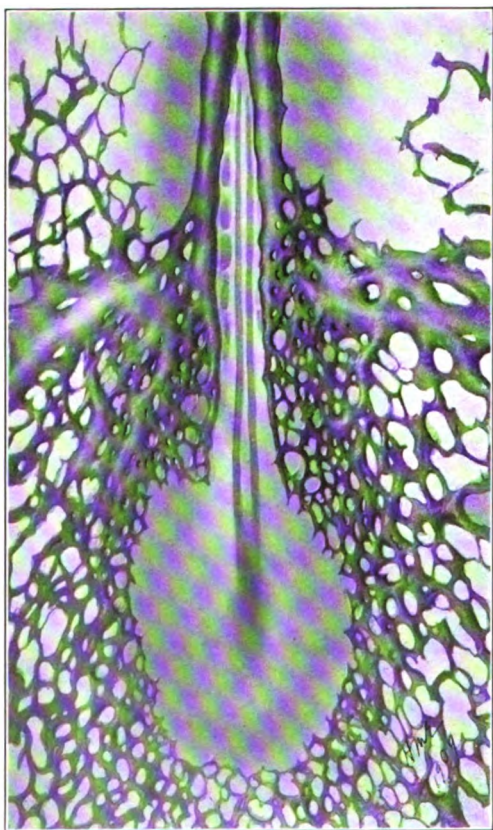


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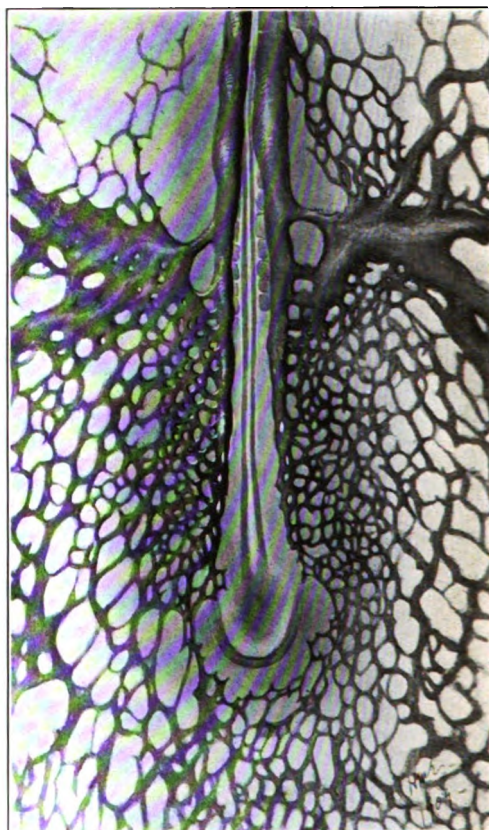


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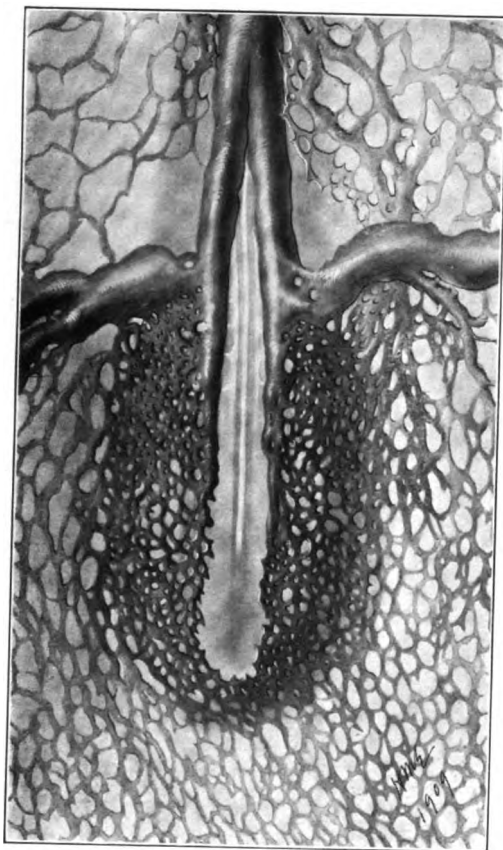


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BLOOD VESSELS OF VERTEBRATE EMBRYOS.

HERBERT M. EVANS.

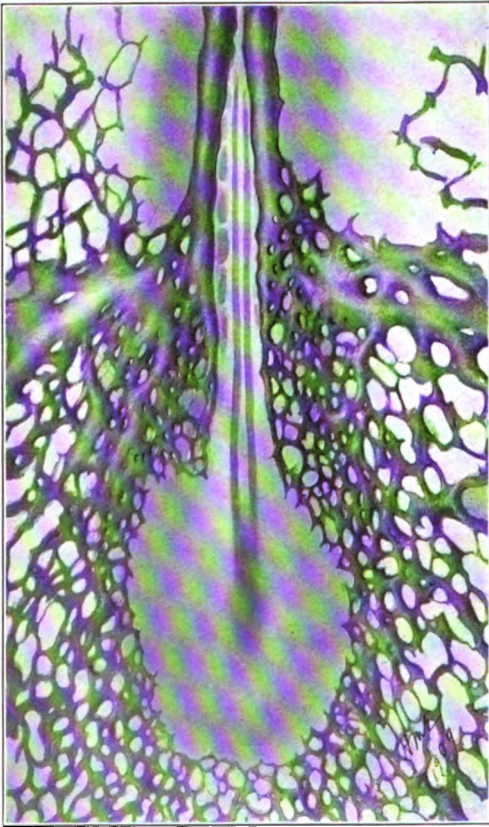


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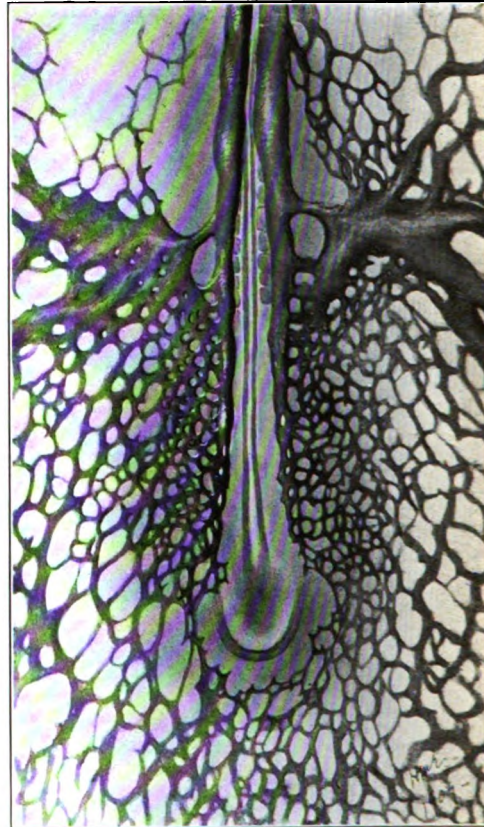


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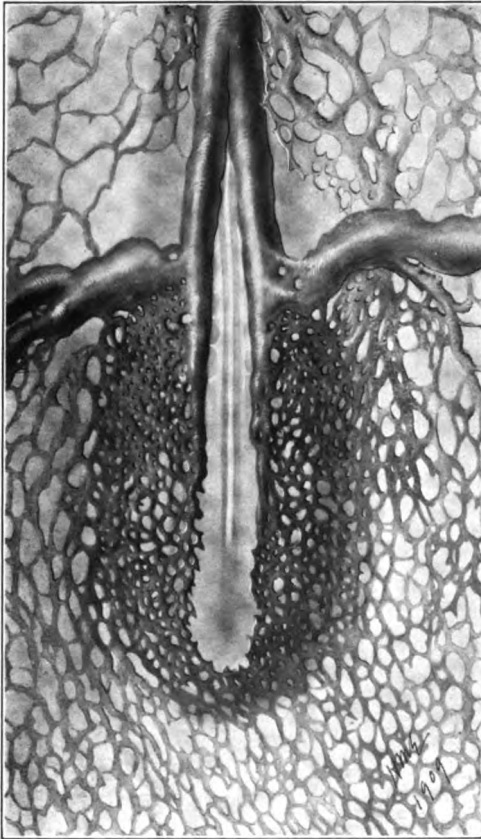


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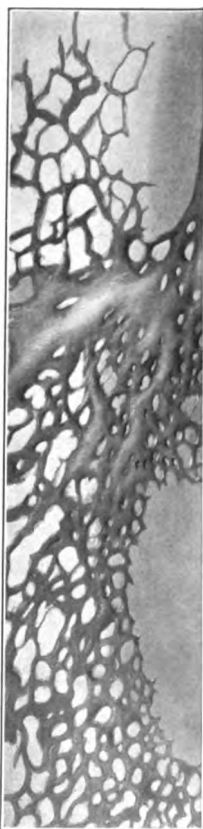
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That portion of the plexus formerly occurring in the region from the fifteenth to the twentieth somites has had its most medial margin enlarged into the continuation of the aorta on each side, but this has involved also the elimination of its former frequent connections in this region with the remainder of the mesh. Some of the steps in this process are to be seen beginning in the mesh now present below the level of the twentieth somite, for in the upper portions of this the medial margin of the plexus is distinctly accentuated above its fellows, with which, however, it is still in continuous communication.

From now on, in successive stages, there is continued caudally this invasion of capillaries and the conversion of the innermost strand of the plexus into the continuation of the aortæ.

Such a conception of the development of the aorta, I find was clearly indicated by His and especially by Vitalleton. The single figure of His showing one of the stages in this process gave the clue to the story, but, doubtless due to the difficulty in recognizing the limit of capillaries by ordinary methods, Rückert and others have not accepted these views. Our preparations, however, have given in all its details this method of the formation of the lower aortæ.

It is interesting to note that the many connections of the aortæ with the plexus from which they have been formed persist for a long time in the area below the level of origin of the main vitelline arteries. They may be said to form the primary circulation of this portion of the intestine, for, when the caudal vitelline vein is established and comes to encircle the posterior intestinal portal, these tiny vessels, coursing in the splanchnopleure, connect the aortæ with this vein.

ANTERIOR CARDINAL VEINS.

At the same time that capillary growth begins to more actively extend the aortæ caudally, *i. e.*, at the stage of fifteen somites, significant changes also begin in the region of the head. Here the earliest capillaries to grow out independently into the tissues of the embryos have arisen from the cephalic convexity of the first aortic arch and, extending dorso-laterally, formed a few meshes opposite

the constriction between fore and mid-brain. From here the capillaries spread forwards and backwards, growing somewhat more rapidly in the latter direction, so that a small plexus is soon formed at the side of the mid-brain. Anteriorly, the sprouts tend to encircle the stalk of the optic vesicles. At other points more caudad the dorsal aortæ give rise to capillary sprouts which grow forwards and join those just mentioned and growing also in the opposite direction, coalesce with the vitelline veins near the junction of the latter trunks with the heart. Thus a slender but continuous chain of capillary vessels extends from the head region to the vitelline veins. Evidently enough of a circulation exists through this minute head plexus, fed as it is at several points from the aortæ, to fashion a venule from the more caudal capillaries, *i. e.*, those opposite the hind brain, so that at a very early date we have the picture of a long slender venule leading back from the plexus at about the region of the isthmus between mid and hind-brain to the vitelline veins near the heart.

It is out of this capillary plexus which has begun to grow up about the mid and fore brain vesicles that the head veins are all ultimately formed. These veins are the chief tributaries of the anterior cardinal trunk and consequently extend the latter vessel much forward into the region of the head.

In all vertebrate embryos which I have studied, a portion of this capillary plexus opposite the mid-brain soon lies more superficially than the remainder and it is from these capillaries, enlarging soon, that the main vein is destined to be continued. This interesting stage in the development of the head vessels is seen in Figs. 4, 5, and 6.

It is thus possible to trace the history of all the head tributaries of the anterior cardinal. Out of the capillaries connecting the more superficial ones just mentioned with those surrounding the sides of the optic vesicle, are formed the ophthalmic veins. And at the same time the caudal margin of the plexus covering the mid-brain is enlarged to form a prominent drainage channel, a vein which is thus situated at the isthmus between hind and mid-brain or at the caudal edge of the latter vesicle.



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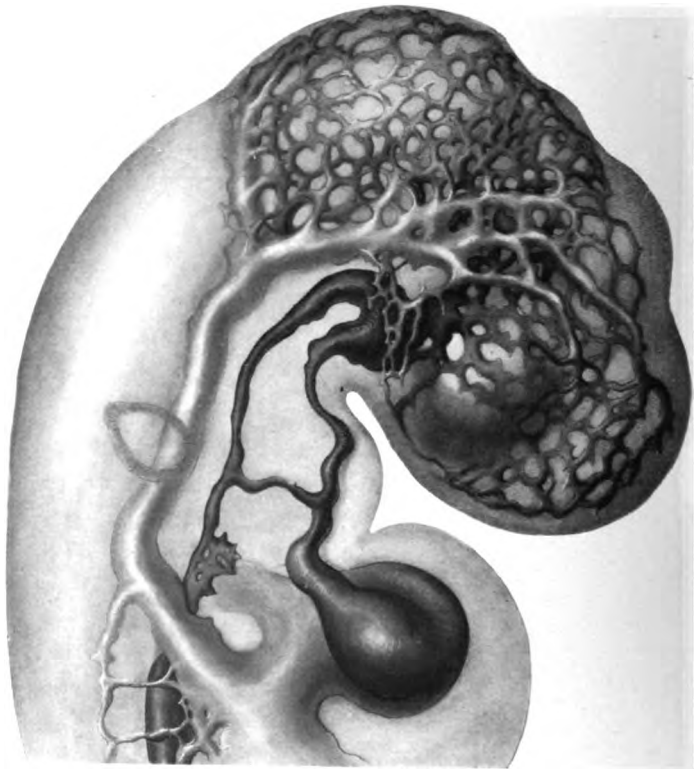


FIG. 6.



FIG. 3b.



FIG. 4.

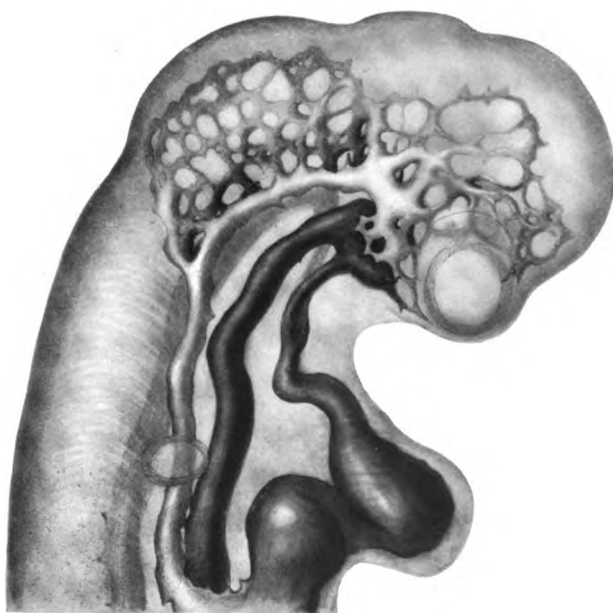


FIG. 5.

POSTERIOR CARDINAL VEIN.

The origin and development of the *posterior cardinal vein* whose entire history can be followed, is the result of the activities of two systems of capillaries, a chain of capillaries arising from the duct of Cuvier and growing caudally in the splanchnopleure, and a row of capillaries, the intersegmental vessels, which in simple loops spring from the aorta and annex themselves successively to the former chain. What guides the course of these particular capillaries—the segmental vessels—so accurately into these loops is at present unknown, but it is no doubt a direct influence of the segmental structure of the neighboring mesenchyme which only favors endothelial proliferation at the inter-somitic spaces. Hence it is that at these intervals, the segmental capillaries (to become later the segmental arteries) grow out at right angles to the main axis of the embryo and after a dorso-lateral loop or bend are free to extend longitudinally. Such a longitudinal extension involves their union with the capillary chain which

FIG. 3b.—Lateral view of head of injected chick embryo of 15 somites, showing primary head capillary plexus. The plexus takes origin from the convexity of the first aortic arch at several points and is continued posteriorly as a slender capillary chain which eventually joins the main vitelline vein near its junction with the heart. This slender capillary chain has arisen at several points from the dorsal aorta on each side, and two of these points of origin are still preserved, opposite the region of the hind brain. The delicate capillary path from the head plexus to the vitelline vein is destined to form the anterior cardinal vein.

FIG. 4.—Lateral view of head of injected chick embryo of 17 somites, showing the primary head capillary plexus partially covering the lateral sides of the fore and mid-brain vesicles. It will be seen that a portion of the plexus lies more superficially than the remainder, and it is this superficial portion which is destined to become the main trunk of the vein in this region. The artery is shown darker than the vein.

FIG. 5.—Lateral view of head of injected chick embryo of 20 somites, showing the further development of the anterior cardinal vein out of the primary head capillary plexus. The capillaries bordering the groove between mid and hind brain have formed a prominent tributary of the main vein.

FIG. 6.—Lateral view of head of injected chick embryo of 25 somites. The lateral surfaces of the fore and mid brain vesicles are now completely covered by the capillary net, which is extending dorsally but is still far from the mid-dorsal line. There is seen a corresponding great growth of the anterior cardinal vein and its system of tributaries.

has grown down from Cuvier's duct and thus this channel is extended. Beyond the first four or five segments, this channel consists often of a single longitudinally coursing capillary and it is now further

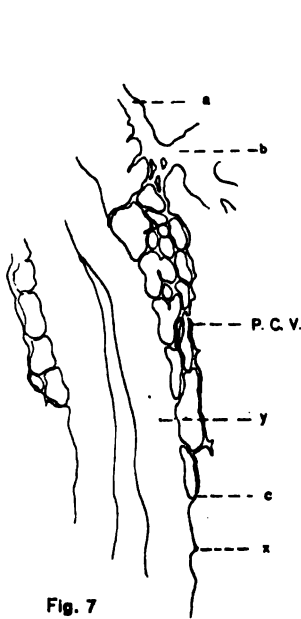


Fig. 7

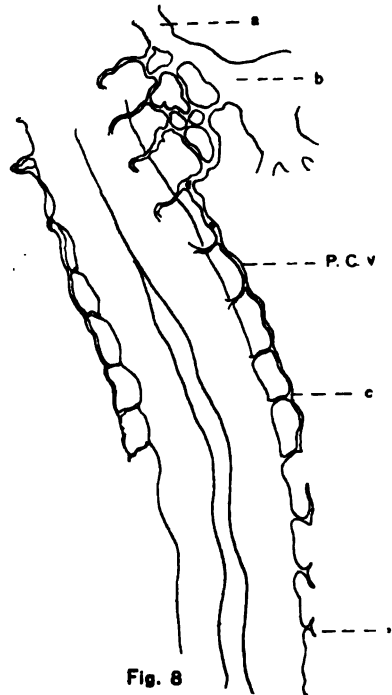


Fig. 8

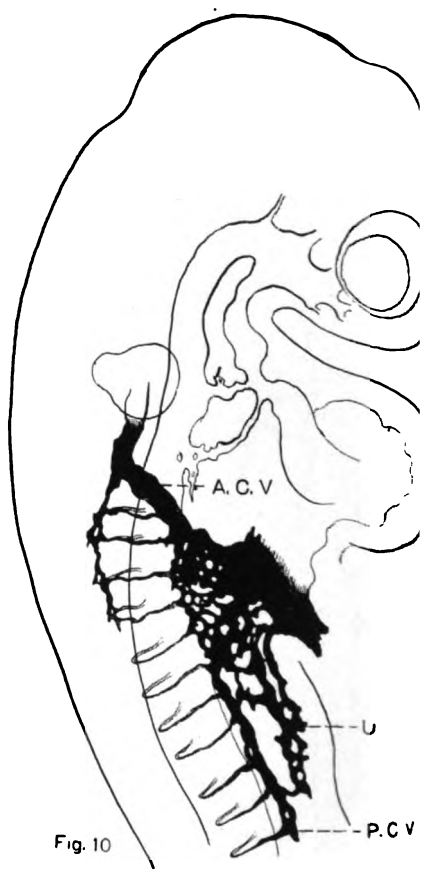
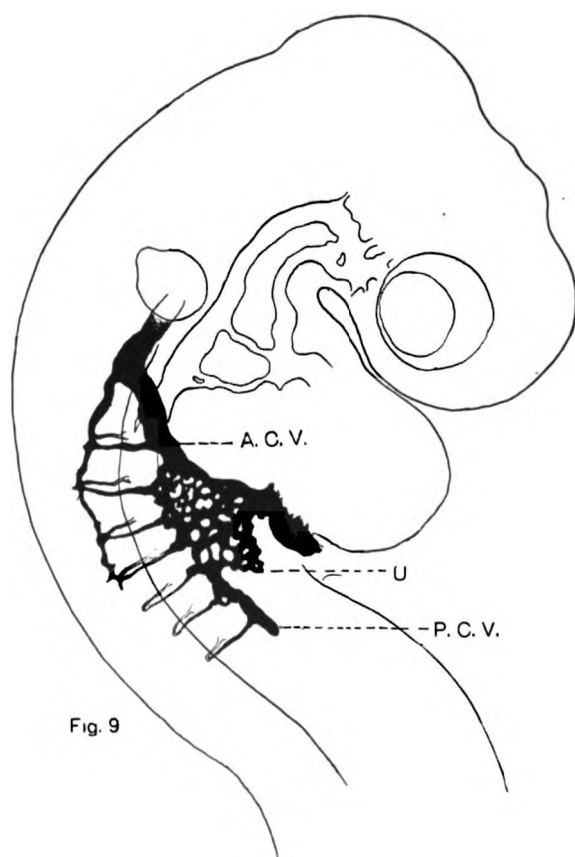
FIG. 7.—View of a total mount of an injected chick embryo of 17 somites, showing the duct of Cuvier and subadjacent region. ($\times 80$.) a = anterior cardinal vein; b = duct of Cuvier; c = 10th segmental vessel; P. C. V. = capillaries from which the posterior cardinal vein is formed; x = endothelial sprout representing the 11th segmental vessel.

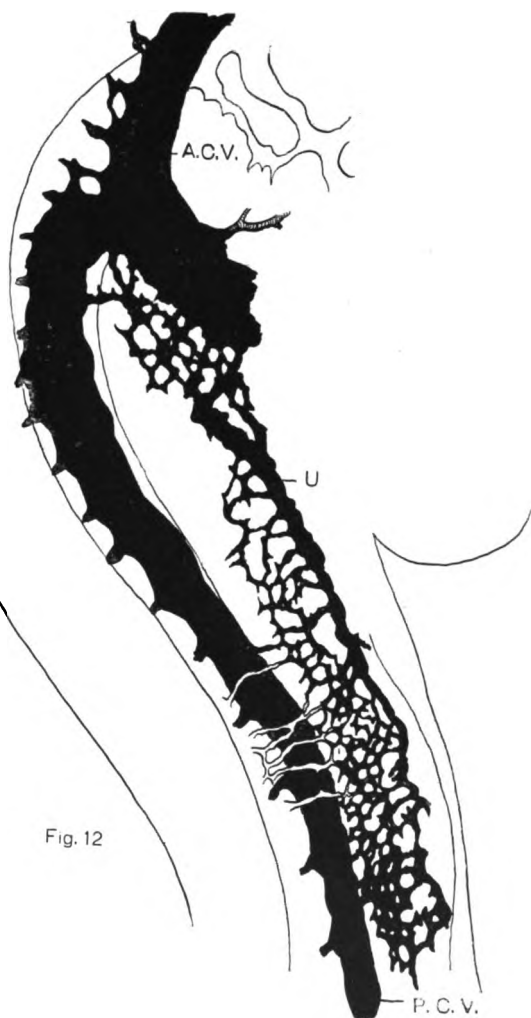
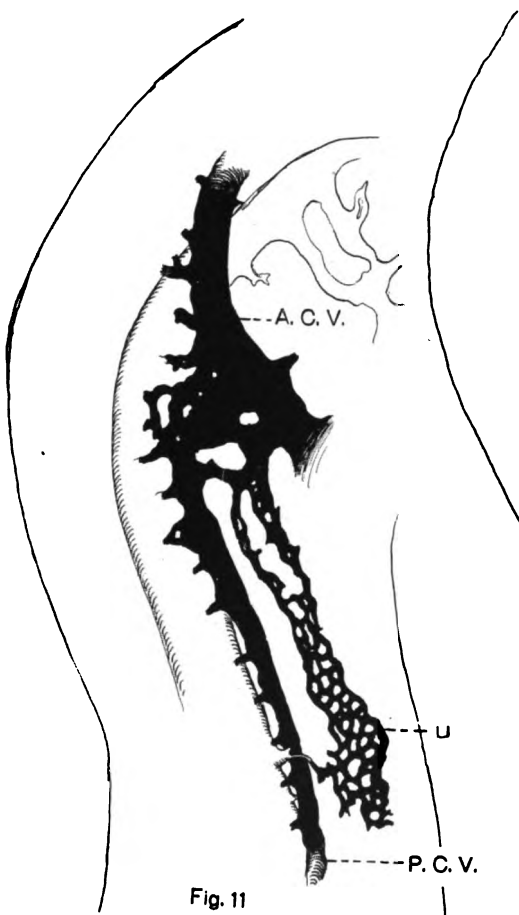
FIG. 8.—View of a total mount of an injected chick embryo of 21 somites, showing the duct of Cuvier and subadjacent region. ($\times 80$.) The lettering is the same as in the preceding figure, with the exception of x, which represents the 14th segmental vessel. One sees the segmental capillaries bifurcate often into anterior and posterior sprouts, the union of which makes the continuation of the vein.

extended caudally solely by the longitudinal sprouts of the segmental capillaries, the cephalic sprout of the last of these joining the caudal sprout of the next preceding one as Figs. 7 and 8 show. Coin-

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cident with the extension of this vessel its upper section becomes larger, for the increased number of segmental afferents gives a considerable drainage territory; thus it is that it soon becomes a vessel of more than capillary size and recognizable as the posterior cardinal vein.

UMBILICAL VEIN.

Those irregular capillary meshes which border the duct of Cuvier in embryos of from fifteen to seventeen somites and which aid in the formation of the upper end of the posterior cardinal vein, after a considerable interval, again sprout caudally, this time in the somatopleure, and are developed later into the veins which we can recognize as the umbilicals. The history of these veins in the chick is fraught with the greatest interest, for by the injections we can follow them in the assumption of several rôles in the embryonic circulation, long before the establishment of their ultimate function in connection with the allantois. They are successively the drainage channels of the arm, the body wall, and the leg before the allantois has arisen. The latter sac indeed attains some little size before its vessels are in connection with the umbilical veins.

By the stage of twenty-three somites the first capillaries of the later umbilical vein form a simple mesh work in the uppermost portion of the somatopleure. Soon the cell mass constituting the future anterior limb becomes evident and its growth stimulates the

FIG. 9.—Injected chick embryo of 23 somites to show the origin of the umbilical vein from a capillary plexus situated in the angle between the posterior cardinal vein and the duct of Cuvier. A. C. V.=anterior cardinal vein; P. C. V.=posterior cardinal vein; U=capillaries destined to form the umbilical vein.

FIG. 10.—Injected chick embryo of 24 somites to show the extension in the somatopleure, of capillary plexus forming the umbilical vein. The lettering is the same as Fig. 9.

FIG. 11.—Injected chick embryo of 30 somites. The capillaries destined to form the umbilical vein have reached the region of the future arm bud where they are joined by a direct capillary sprout from the aorta (subclavian artery).

FIG. 12.—Injected chick embryo of 35 somites, showing establishment of umbilical vein as the main drainage channel of the anterior limb.

outgrowth from the aorta of a whole series of capillaries which unite to form a delicate plexus. These capillaries find and unite with those which have grown down from the duct of Cuvier and thus is

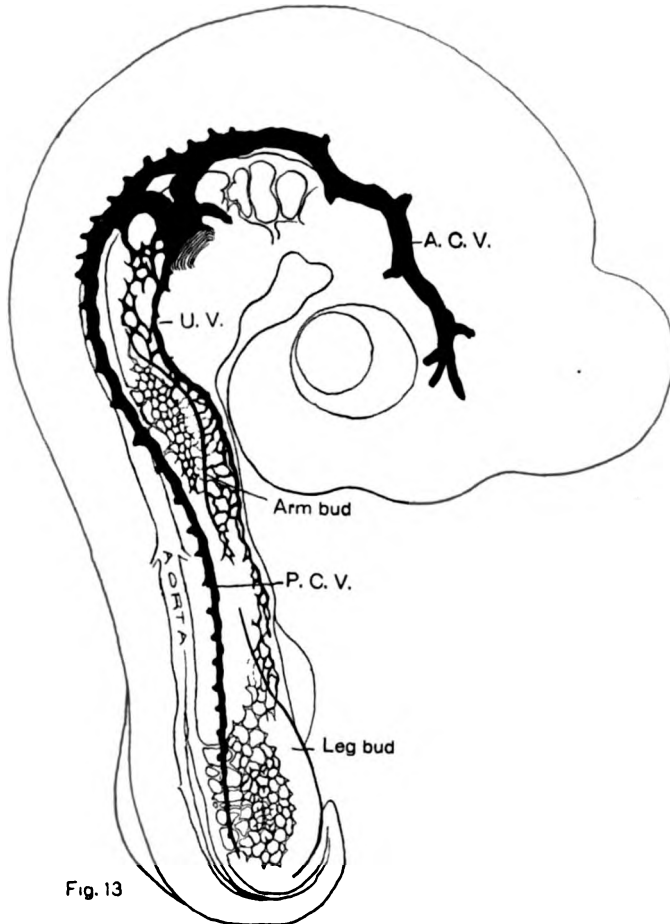


Fig. 13

FIG. 13.—Injected chick embryo of the third day showing extension of capillaries from which the umbilical vein is formed, as far as the posterior limb bud. The reduction is much greater than in the preceding figures in order that the entire embryo can be shown.

established the earliest circulation in the limb bud, a circulation consisting of many afferent capillaries streaming from the lateral

aortic wall, forming in the limb tissue a few simple meshes and draining headwards into the capillary chain, already somewhat enlarged and venous in character, which is the later umbilical vein.

This capillary net still continues to grow caudally in the somatopleure, below the level of the upper limbs. At the same time another mesh of capillaries, that which has arisen in the posterior limb buds, has begun to grow upwards and the union of these two plexuses establishes a narrow continuous mesh in the somatopleure,

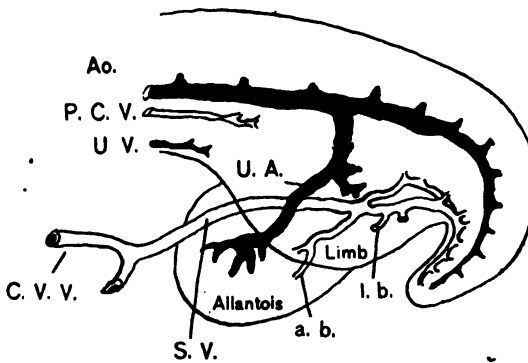


Fig. 14

FIG. 14.—Caudal end of an injected chick embryo showing the subintestinal vein draining the tail, allantois and posterior limbs. a, b.=allantoic branches; l. b.=limb branches; S. V.=subintestinal vein; P. C. V.=posterior cardinal vein; Ao.=aorta; C. V. V.=caudal vitelline vein; U. A.=umbilical artery; U. V.=umbilical vein.

into which the vessels of both limb buds and the body wall now drain. The capillaries of the hind limbs have also acquired connections with a more ventrally placed vein—the sub-intestinal vein, which has arisen in connection with the drainage of the tail and the allantois. This vein has hitherto been entirely overlooked and its presence in any of the embryos of the higher vertebrates is entirely unknown save for a few sentences announcing its occurrence in the ninety-six hour chick in the recent work by Lillie.⁷ His remarks on the discovery of this vessel can be very appreciably extended now

⁷Lillie. "The Development of the Chick," 1909.

from the injections. As has just been indicated, the sub-intestinal vein in Aves forms the primary drainage channel for the tail, hind limbs and allantois. Its position and chief tributaries can be seen from Fig. 14. Somewhat later, and at about the time the allantois approaches a millimeter in diameter, the umbilical system of capillaries has united with its vessels and begins to function as a means of drainage for the allantoic circulation. The uppermost portions of the umbilical have now enlarged appreciably, its connections with both limb buds are eventually lost and its last territory supplies it with such a volume that it becomes a relatively huge channel, the allantoic or umbilical vein.

In the Mammalia, although the umbilical veins precede the limb buds in time of appearance, nevertheless here also, when the limbs arise, they are at first drained into the umbilical veins.⁸

Dr. F. T. Lewis informs me that he had observed and demonstrated this drainage of the mammalian limbs into the umbilical veins at the meeting of this association in 1903. Unfortunately no record of this was made in the proceedings for that session, but Dr. Lewis has been kind enough to send me sketches and notes made at the time, showing this fact for rabbit embryos. I have recently been able to confirm these findings on the human embryo also, so that there is little reason to doubt its general applicability for the Mammalia.

Many other prominent vessels in the body have been traced to a similar origin from a capillary plexus, but time will now permit the mention of only a few of these. In reconstructions of the vessels of the head which have been made by various investigators, it appears as if the tip of the anterior cardinal veins grew forwards in a dorso-medial position, in place to form the future *sagittal sinus*. It has been possible to trace the formation of this vein quite completely in injected mammalian embryos. In pig embryos five and six millimeters in length the primitive capillary plexus which grows up over the sides of the mid and fore brain has not yet reached the dorsal surface, though sprouts can be seen along its upper margin. By the

⁸Evans. Am. Jour. Anat. IX, 2, 1909.

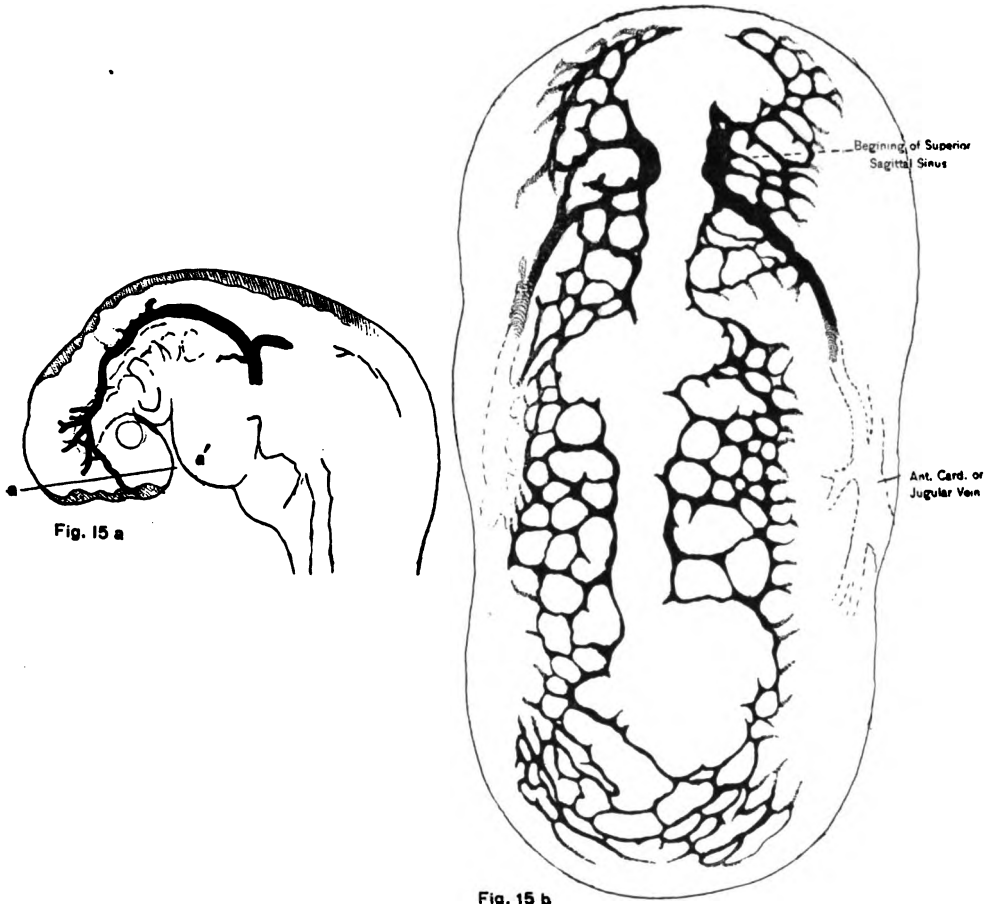


FIG. 15 a.—Lateral view of upper portion of pig embryo 8 mm. long, showing location of mid dorsal non-vascular area, the extent of which has been purposely exaggerated laterally. It will be noted that the capillaries have fused dorsally over the mid brain and upper portion of the hind brain.

FIG. 15 b.—Dorsal view of fore and mid brain region of the pig of 8 mm. shown in Fig. 15 a, showing the limit of extension of the capillary plexus here. The mesh work which has grown dorsally from either side halts sharply in two parallel lines between which is the narrow non-vascular strip. Anteriorly is seen the earliest indication of the superior sagittal sinus, which is formed from either margin of the capillary mesh, and consequently at this stage paired.

time the embryo has attained a length of nine millimeters, the capillary mesh has covered the top of fore and 'tween-brain vesicles save in the median line. Here the two meshes are as yet unfused, and confront each other along two parallel lines, which thus bound a median dorsal non-vascular strip, across which no connecting capillaries have ventured to grow. It is these two medial margins of the plexus which, in the region of the cerebral hemispheres, are enlarged to form the superior sagittal sinus, thus originally paired. (Figs. 15a and 15b.)

One of the most beautiful and evident instances of the conversion of a capillary mesh into an arterial channel is afforded in the history of the *anterior spinal artery*. Here too we have the best possible axis of reference, for the mid-ventral line of the spinal cord is constant. On the ventral surface of the cord we can observe all the steps in the first invasion of a plexus of capillaries there, their later coalescence and enlargement in the mid-line as an irregular, ill-defined channel, and eventually, the further conversion of this into the very definite artery of regular contour and calibre—the anterior spinal. Fig. 18 illustrates the development of this vessel in the pig.

I may be permitted to instance one more vessel, in this case one of the very largest in the body, though not the earliest to develop, which can easily be seen in the young embryo in the form of a capillary mesh. I refer to the pulmonary artery. The endothelial sprouts which later form this trunk spring from the sixth aortic arch as true capillaries. In fact they reach the lung bud as a chain of capillary meshes and retain this character for some time, as Fig. 21 shows.

Besides the history of many individual blood vessels of the body, these specimens have given weighty evidence towards a number of general laws or phenomena of blood vessel development and these will be briefly mentioned. They concern

(1) The presence always in the embryo, of a united vascular system, so that the blood vessels form a single though irregularly branched endothelial tree whose branches are in no case added after an independent formation but arise by sprouting from the parent trunks.

(2) The place and manner of spread of the first capillaries through the body.

In discussing these briefly, we may say

(1) Serial sections of perfectly injected embryos show no evidences of vessels which have not received the injection mass and are hence unconnected with the general system. Investigators, working with uninjected material, have repeatedly reported such vessels. Their findings are in all probability to be explained by a collapse of the connecting vessels, since

a, injected specimens show these connecting vessels and

b, injected specimens fill other vessels previously unrevealed by ordinary methods, thus furnishing a far more complete picture than is otherwise obtainable.

The recent accounts by Rückert and Mollier in Hertwig's Handbuch, on the subject of the first blood vessels are perhaps the most conspicuous of the claims of vessel origin in situ. Their evidence has come from Rückert's studies of serial sections through selachian embryos. His statements can doubtless be successfully attacked by injecting selachian embryos and studying carefully the areas in question.

With the light which such specimens have shed, the statement that any vessels in the embryo arise at first unconnected with the vessels in that region can be now challenged. If an instance be given it can doubtless be speedily disproven, providing complete injections of that area can be secured.

(2) The spread of the first vessels through the body. Whatever may be the first source of the endothelium in the body of the embryo, after the earliest stages, the injections have furnished a complete history of the further capillary proliferation and outgrowth into the tissues of the embryo.

Inasmuch as the first vessels lie somewhat centrally in the embryonic body, the general direction of growth is from center to periphery. The center consists of the upper dorsal aortæ together with the first arch and Cuvier's duct; the periphery comprises the various viscera and central nervous system as well as the body wall, but the ultimate periphery, the skin, is supplied late.

In spreading outward, the capillaries do not grow uniformly in all directions, thus successively invading various zones, but are apparently governed by the character and needs of the various tissues, reaching some of them early and some remarkably late. Hence there are present during all the early stages in the embryo's growth, vascular and non-vascular areas.

The method of injection reveals such a wealth of small vessels whose existence we had not hitherto known, that at first thought one is inclined to suspect the universal presence of the vascular net, throughout the tissues of the embryo. This, however, is as much an error as was the former notion of the scant extent of the embryonic vessels. Injections made under the best possible conditions and afterwards explored in serial section have all shown the existence of definite non-vascular areas bordered by a margin of true capillary sprouts. *The position of such non-vascular areas is as constant as is that of any vascular channel in the body and the more fundamental of them are probably represented at homologous stages in all vertebrate embryos.*

Among the tissues, the central nervous system receives the first investing capillary net, but even here the capillaries do not at once surround the neural tube but occupy only the lateral aspect, gradually growing ventrally and dorsally. At the top of the brain, the capillary mesh is some time in fusing from either side, so that there exists here relatively late the narrow non-vascular strip in the mid-dorsal line already mentioned. (Fig. 15.) In the case of the hind brain there is an especially conspicuous lack of much capillary proliferation in a dorsal direction, so that in comparatively late stages of all vertebrate embryos the roof of the hind brain presents a characteristic large non-vascular zone. Indeed, while in pig embryos ten millimeters in length the lateral capillary beds have completely fused dorsally, in the fore and mid-brain region, the non-vascular area on the top of the hind-brain persists until the embryo has attained a length of over twenty millimeters. (Figs. 16, 17a, and 17b.)

In the cord also the ventral and dorsal surfaces are invaded only secondarily and are at first entirely non-vascular. The dorsal sur-



FIG. 16.



FIG. 17b.

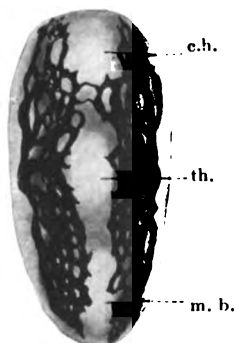


FIG. 17a.

face is bridged last of all and so the spinal axis presents for a time the remarkable sight of a close capillary investment everywhere save on its upper aspect, at the margins of which the two long parallel borders of invading capillaries and their sprouts have halted sharply in their spread. (Fig. 19.) This narrow non-vascular zone is maintained for a long time, but when the time comes for its obliteration, quite suddenly, capillary sprouts push out and bridge the gap. This bridging occurs successively from above downwards and embryos which have the dorsal surface thickly covered with capillaries in the upper half will show the first bridging capillaries in the caudal region, as Fig. 20 shows.

Other examples of vascular and non-vascular areas may be mentioned. The center of each sclerotome is, on its upper surface, supplied by a sheet of closely anastomosed capillaries; but the outer divisions of the sclerotome are not so supplied. There capillaries are absent for a considerable time, so that the vertebral column presents a succession of vascular and non-vascular zones, the former areas in each case overlying the segmental vessels.

Furthermore, in the growth of the embryo, tissue at one time permeated with a quite uniform capillary mesh may in its further growth show a later differentiation into vascular and non-vascular areas. This arrangement of its vascular mesh is of course coincident with corresponding changes in the nature of the tissue at various

FIG. 16.—Dorsal surface of hind and mid brain of a pig embryo 8.5 mm. long, showing fusion of the primary head plexus across the mid line, except the three non-vascular areas shown.

FIG. 17 a.—Dorsal surface of fore and mid-brain vesicles of injected chick embryo of 32 somites.

FIG. 17 b.—Dorsal surface of fore and mid-brain vesicles of injected chick embryo at the end of the 3d day. c. h. = cerebral hemisphere; th. = thalamencephalon; m. b. = mid brain. In the earlier stage (Fig. 17 a) the primary head capillary plexus has fused across the mid dorsal line only at one point, between the two divisions of the primitive fore brain. In the later stage the mesh quite completely invests the mid dorsal surface of the head, but the cleft between the cerebral hemispheres is non-vascular, as is also the zone surrounding the pineal organ. At the mesial margins of the two prominent lobes of the mid brain are seen the two mesencephalic veins which have been formed from the plexus.

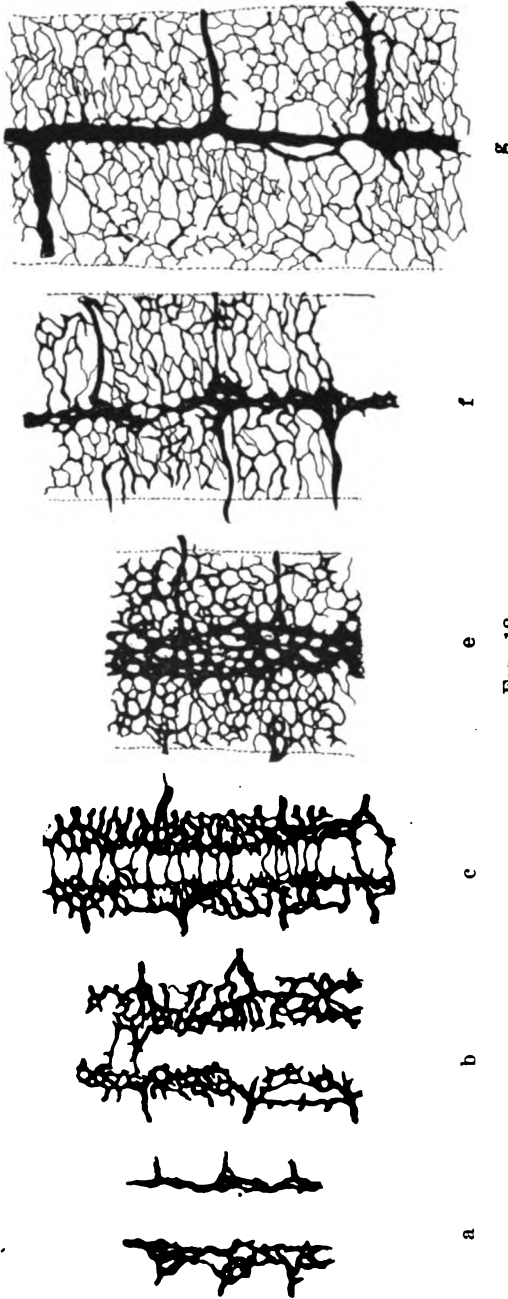


FIG. 18.

FIG. 18.—The ventral surface of the spinal cord in the region of the first three thoracic segments in a series of injected pig embryos, showing the origin and development of the anterior spinal artery. $\times 33\%$. a, from an embryo 6 mm. long. No capillaries appear on the ventral surface, those seen invest the lateral surface and the ganglia. b, from an embryo 8.5 mm. in length. Capillary sprouts are seen invading the ventral surface of the cord. c, from an embryo 9 mm. long. The sprouts shown in the preceding figure have now extended as delicate straight parallel capillaries which bridge the mid line, so that the non-vascular area there is now obliterated. e, from an embryo 14 mm. long. The processes of endothelial coalescence suggested in the preceding stage have resulted in the formation of an irregular fenestrated mid-ventral channel, in freer communication at intervals with the ventral branches of the segmental vessels; f, from an embryo 15.5 mm. long, the mid-ventral channel has become narrower and its segmental afferents much stronger; g, from an embryo 28 mm. in length. The arterial character of the mid-ventral channel is now apparent, some of the segmental afferents have disappeared and others have been much exaggerated in growth. The capillaries everywhere are of smaller caliber than those found in the earliest stages.

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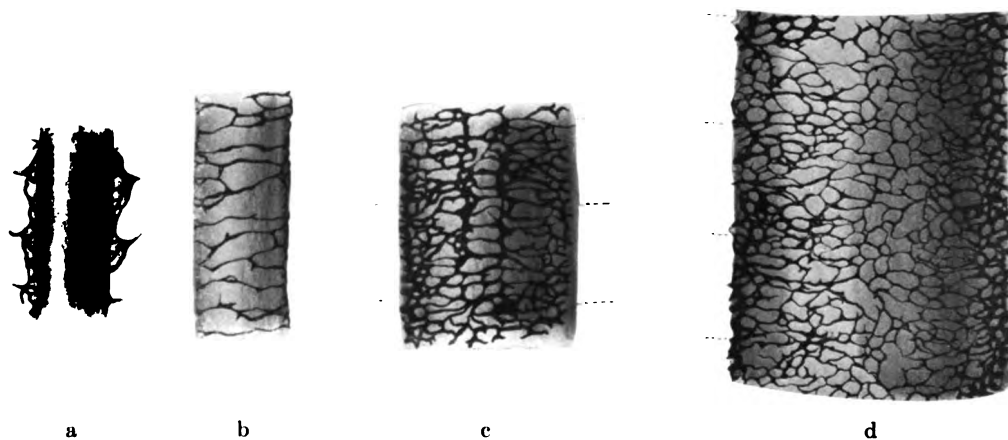


FIG. 19.

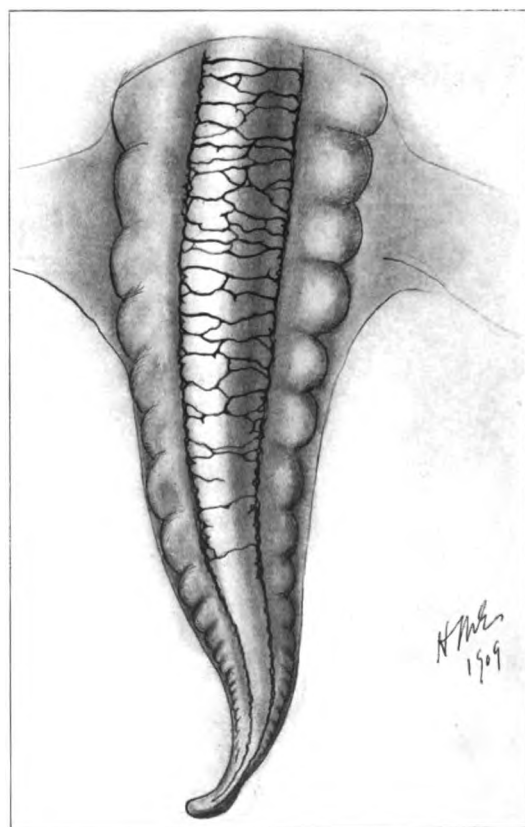


FIG. 20.

areas and it is often the most positive evidence of these changes. Thus pre-cartilage and pre-muscle tissue are characteristically non-vascular and wherever these condensations of the mesenchyme occur, they

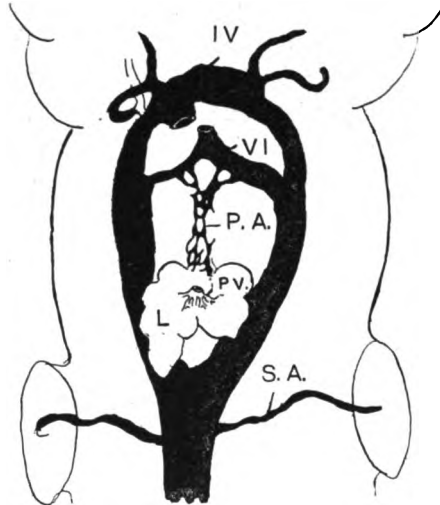


Fig. 21

FIG. 21.—Camera lucida tracing of the fourth and sixth aortic arches of an injected pig embryo 12 mm. long to show the early character of the pulmonary arteries. P. A. = pulmonary arteries; L. = lungs; P. V. = pulmonary vein; VI = sixth arch; IV = fourth arch; S. A. = subclavian artery.

form islands of tissue sharply circumscribed by capillaries but uninvaded by the latter for a considerable interval. Of this the limb buds furnish splendid examples, for the blastema of the arm, which is at first furnished with a uniformly distributed capillary net, later

FIG. 19.—A series of views of the dorsal surface of the spinal cord at the level of the lower cervical segments in injected pig embryos. a, from an embryo 8 mm. in length. All the capillaries seen are limited to the lateral surfaces of the cord and the spinal ganglia. b, from an embryo 10.5 mm. long, showing the first capillary bridges across the cord in this region. c, from an embryo 15 mm. long, showing the type of plexus established here. d, from an embryo 20 mm. long, illustrating the farther growth of the plexus.

FIG. 20.—Tail of an injected pig embryo, 13.5 mm. long. In the cervical and thoracic regions, the plexus investing the dorsal surface of the cord has become a close mesh; in this region, however, the first capillary bridges, and, at the end, the first sprouts, are shown.

begins to exhibit areas which the capillaries appear to avoid—areas corresponding to the later masses of cartilage or muscle groups.

In most cases the capillaries tend to anastomose at greater or lesser intervals forming a loose or close mesh and this plexus formation is doubtless one of their most characteristic and fundamental properties. It has perhaps been better termed their tendency to grow in every direction, yet influences often check this tendency successfully and in some areas permit their growth from the very first only in a certain definite direction. The best example of this is furnished by the dorsal segmental vessels which, as is well known, are rigidly governed in position by the presence of the primitive segments, between which they course.

All of these examples clearly indicate that the behavior and character of the capillaries is even from the very first intimately influenced by the tissues into which they grow. A new set of problems confronts us, problems which can aim more than ever before at the causes at work in the developing organism, for now that we may recognize with certainty vascular and non-vascular areas and the relation of each of these to the tissues, there come up at once questions concerning the differences in chemical nature of the tissues and a closer determination of the real stimulant for vascular growth.

The story of the development of the vascular system is primarily the story of the spread of the capillaries, the form and relation of their plexuses and the rôle of these in the elaboration of the trunks of the adult.

We have to do always with the extension of a functioning system not the blind outgrowth of vessels to their ultimate territory. Such a system extends itself by capillary sprouts and as the capillary bed increases, its supplying and draining channels, the arteries and the veins, grow and rearrange themselves concordantly.

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THE RELATION OF PRESIDENT GILMAN TO MEDICAL EDUCATION.

BY

WILLIAM H. HOWELL.

Dean of the Medical Faculty, Johns Hopkins University.

Whenever, since Mr. Gilman's death, I have attempted to formulate for myself an estimate of his services, I have finally summed it all up in an expression of his own, which I heard him use on the occasion of the memorial exercises to the late Professor Rowland. I remember the occasion well. As he advanced to the edge of this platform to open the exercises, looking silently at his audience for a few seconds, he began his remarks by the simple sentence, made impressive by his manner, "A great man has fallen in our ranks." I am confident that this estimate, applied to him, is shared by every one in this audience and by all of our fellow alumni of the Johns Hopkins University. He was a great man, and above all a great college president. He was a great president by virtue of the fact that he was a man of ideas and high ideals which reacted like a stimulus upon all who were brought into contact with him; he was a great president because of his masterly genius for organization; but he was a great president chiefly, in my judgment, because he possessed in such large degree the rare power of getting the best out of those who worked with him and under him. He led and guided them by the all-constraining force of his enthusiasm, his sympathy, and his tact. The kind of executive who drives things before him by the mere force of his personality, is liable, in accordance with the law of action and reaction, to create round himself an atmosphere of opposition and discontent. Such an executive may be needed in some of the affairs of life, but he is not the type most suited to develop the greatest efficiency of a university faculty. This University was most fortunate in possessing in Mr. Gilman a leader and executive who, by reason of a happy

combination of genial qualities of mind and heart, was able to inspire a general and enthusiastic spirit of co-operation among his official subordinates. We must never forget, nor allow others to forget, that the great success which this University attained, almost from the beginning, was in a large part, in chief part, due to him. The creation of a university of a new type was not a game that played itself. On the contrary, there was opportunity in abundance for mistakes and disaster, and if, instead, there came, on the academic side, a train of successes and renown, we owe it largely to his ability and experience as a leader and administrator.

I have been asked to speak of Mr. Gilman, especially in regard to his connection with the medical school. In truth the medical department owes as much to his wise and stimulating leadership as its older comrade, the philosophical faculty. It is well known that the subject of medical education interested Mr. Gilman deeply. What circumstances gave this direction to his thoughts I am not able to say from personal knowledge. I know only that it antedated his connection with this institution. That a special interest existed is evident from his published addresses, as well as from the record of his services while President. In his inaugural address the subject of the formation of a worthy school of medicine comes up first, and the hope is expressed that at no very distant day a medical faculty may be organized. So also, in describing the purpose and aims of the biological department, which constituted a novel feature in the newly-established university, he laid great emphasis upon its importance in relation to the study of medicine. Indeed, from the beginning of the University there was organized a pre-medical course along the lines which had been laid down by Huxley, a course which in its general features, has since been endorsed and imitated by many of the leading schools of the country. As a matter of fact, medical education among us at the time of the founding of the University was in a deplorable condition. Deprived of adequate financial support and without the uplifting aid of an academic connection, most of our medical schools had sunk to a very low level. They demanded practically no educational preparation on the part of their matriculates, and they made little or no effort

to give their students an adequate training in the theory and science of medicine. The training, in fact, resembled that of an apprentice rather than that of a candidate for admission to a learned profession. Mr. Gilman, with his wide interest in education in general, must have been impressed, as many other thoughtful men were, with this very undesirable state of affairs. With the prevision characteristic of a great leader, he seems to have selected medical education as one of the great opportunities which the new university might utilize to do a needed service to the country at large. For reasons over which he certainly had no control the realization of his plans was deferred for some seventeen years. It was not until 1893 that the medical school, as we now know it, was founded. It was and is a graduate school in the sense that it accepts as students only those who are college graduates. At the time of its foundation its requirements for entrance seemed almost absurdly high. It was supposed that only a few students each year would be willing to meet these requirements, considering that in the other leading schools the conditions for entrance were so much less difficult; and the idea that our standards would ever be adopted generally by other schools was scarcely reckoned among the probabilities. Yet, to-day, this school has three hundred students upon its rolls, and for many years past there has been a steady approximation on the part of other good medical schools toward the standards established here. Many agencies have undoubtedly contributed to the great improvement in medical education which has taken place in this country during the last generation—volunteer organizations among high-minded physicians, the effective action of our State Boards, etc.,—but I believe it will be admitted that the actual example held before the eyes of the medical public, in the successful experiment carried out here under Mr. Gilman's direction, has been the most potent influence of all in strengthening the weak faith of those who doubted the feasibility of such a reform.

Many speakers and writers have commented upon the timeliness of the foundation of the Johns Hopkins University. The University was started at a time when the country was ripe for the opportunity to obtain genuine graduate instruction. Certainly

the same observation may be made with even more justice in regard to the appropriateness of the movement inaugurated by the foundation of the medical school. The country was prepared, indeed had been prepared for some years, for a development of this kind. Mr. Gilman and his colleagues had the wisdom to understand this, and the courage to make the experiment on a scale befitting the reputation of the University and worthy of the unique opportunity afforded by the existence and close affiliation of that splendid sister institution, the Johns Hopkins Hospital.

Mr. Gilman's devotion to the affairs of the medical school in its early history was unflinching. He gave to it on the administrative side an ideal organization which has been the envy of other schools, and which will eventually, I believe, be generally adopted. The central feature of this organization is that it places all power in the hands of a small but representative body, composed of the heads of departments, the president, and the superintendent of the hospital. Over the deliberations of this body he presided constantly during his incumbency, and it is needless, for those who knew him, to add that he was a most admirable presiding officer. Courteous, considerate, and informal he invited a free expression of opinion from all, but he knew well the art of controlling gently but firmly all tendencies to useless and diffuse discussion. The routine business was dispatched with promptness, while matters of importance from the standpoint of policy or precedent were treated with care and circumspection. A more harmonious and effective board it would be hard to imagine, and, indeed, how could it have been otherwise with a man like Gilman as presiding officer and a man like Welch as dean and secretary. Our foundations were well laid, and I am sure that the great success of the school, acknowledged everywhere, was a source of the deepest gratification to Mr. Gilman. It may be fairly claimed that it constituted his second great contribution to the educational development of this country. I hope that the future historian of medical education in the United States will not make the mistake of supposing, because Mr. Gilman was not a member of the medical profession, that therefore his connection with this medical school was in any sense perfunctory. On the

contrary, it was real, it was vital, and it was continuously maintained.

He had a clear comprehension of the actual conditions and the needs of medical education, and, I believe, a definite idea of the special traditions which he wished to see established here. He took a direct part in the discussions regarding appointments upon the staff, appropriations for the various departments, the standards for admission and graduation and other matters, great and small, which arose during the formation period of organization. I do not believe that this fact of his constant active participation in the details of administration was a matter of common knowledge outside the small circle of the governing board. I am quite sure, in fact, that the students and graduates of the medical school and many of the members of the faculty have assumed that the labor and credit of the successful foundation of the school belong chiefly to the leading members of its faculty, who by their position naturally represented the department in the eyes of the medical public. But I am also quite confident that these same members of the faculty are ready, without exception, to acknowledge and to insist upon the importance of Mr. Gilman's influence throughout the early years of the school's history. This influence was exerted in many ways and its result may be summed up, I believe, in the statement that there was established in the Medical Faculty a distinctly academic spirit. In many of our strong medical schools it may be said, without injustice I think, that the administration of affairs had absorbed something of the methods of compromise, expediency and personal gain which are so evident in the commercial and political worlds. Considerations of this kind press close upon the administrator, of course, and it is difficult for him to ignore them, but the individual or the institution which keeps its eyes focussed too constantly on such methods suffers in the end from a sort of spiritual myopia. The academic spirit takes the larger view beyond the immediate advantage of the present toward that which is fundamentally true and right, and for such a measure of this nobler spirit as we are fortunate enough to possess we are indebted very largely to the personal influence of Mr. Gilman.

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No. 10

AN OBSERVATION ON THE DEVELOPMENT OF THE MAMMALIAN VOMER.

BY

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From the Department of Comparative Anatomy, Harvard Medical School.

WITH TWO FIGURES.

The name "vomer," given to the unpaired plowshare-shaped bone of the human cranium, has been applied in the works on comparative anatomy to a pair of bones in the skulls of the Sauropsida and Ichthyopsida. This homology, maintained by the earlier writers and by most osteologists up to the present time, is founded largely on the relations of parts in the adult skull. The unpaired vomer of the mammals was explained by assuming it to be the equivalent of a pair fused together, a theory supported by observations on the origin and development of the single vomer in certain teleosts and birds and in man. According to Gaupp¹ true paired *Anlagen* of the vomer have not, however, been seen in the lower mammals.

In 1884 Sutton² proposed a new homology for the mammalian vomer by claiming its presence in the lower animals in the parasphenoid, an unpaired bone in the base of the cranium which exists in all classes from the fishes on, except the mammals. The parts in the mammalian cranium which, according to the theory, should correspond with the ichthyopsidan paired vomers, were found in the palatine

¹Gaupp, E. Die Entwicklung des Kopfskelettes. Hertwig's Handbuch der Entwicklungslehre der Wirbeltiere. 1906, Bd. III, Zweiter Teil, p. 850.

²Sutton, J. B. Observations on the Parasphenoid, the Vomer and the Palato-pterygold Arcade. Proc. Zool. Soc., 1884, p. 566.

processes of the premaxillaries. These processes have been observed by Albrecht, Sutton and others to arise independently of, and subsequently to fuse with, the tooth-bearing portions of the premaxillaries.

In later years, Broom³ has contributed much to our knowledge of the comparative anatomy of the vomer, and with evidence adduced from the investigations of Turner, W. K. Parker, Wilson and Symington, he strongly supports the homology of the mammalian vomer and parasphenoid. As to the comparison of the paired vomers of the lower forms with the palatine processes of the premaxillaries, he does not agree entirely with Sutton. Broom has suggested the term "prevomer" for the category of bones represented by the paired vomers (of other authors) in the lizard, and finds its homologues in the paired vomers of the Ichthyopsida. But in the great majority of the higher mammals the prevomer does not exist, its place being taken by invasion of the palatine processes of the premaxillaries. These are regarded as true portions of the premaxillaries and not independent elements which Sutton considered them to be. In the dumb-bell-shaped bone of *Ornithorhynchus* and in a median ossification in the nasal region of *Miniopterus*, Broom identifies the prevomer. These bones, although azygos in the adult, are both derived from a fusion of a pair of splints underlying the cartilages of the vomeronasal organs.

An objection to the comparison of the mammalian vomer and the non-mammalian parasphenoid lies in the fact that the latter presents in the series of animals a history of retrogression; in the lowest forms the parasphenoid reaches forward to the ethmoidal region, whereas in most reptiles and birds its anterior end is far back and away from this region. A more serious obstacle to the new homology is the circumstance, already mentioned, of the single vomer developing from a pair of centers. The one instance in mammals might well be taken to be an exception to the rule of single origin, if

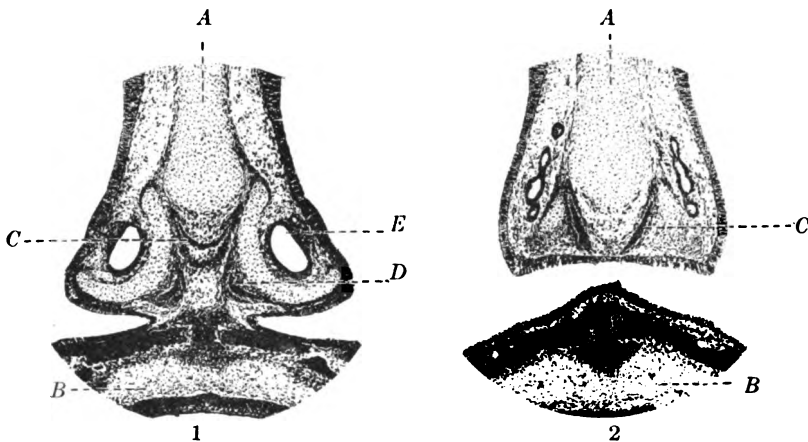
³Broom, R. On the Homology of the Palatine Process of the Mammalian Premaxillary. *Proc. Linn. Soc. N. S. W.*, 1895, Vol. X, p. 477-485.

On the Occurrence of an Apparently Distinct Prevomer in *Gomphognathus*. *Jour. Anat. and Physiol.*, 1896, Vol. XXXI.

On the Mammalian and Reptilian Vomerine Bones. *Proc. Linn. Soc. N. S. W.*, 1902, Vol. XXVII, part 4, p. 545-560.

single origin were known to be the rule. But how many studies have been made by modern methods to determine this matter?

During the reconstruction of the cranium of a cat embryo there was observed a tendency to bilateral formation of the vomer, and my attention was thereby directed to the question of the origin of this bone in the mammals. A review of the series in the Harvard Embryological Collection resulted in finding one instance of paired origin of the vomer, and that in a marsupial. The discovery by Fuchs⁴ of the remains of the parasphenoid in a *Didelphys* embryo and



FIGS. 1 and 2.—Transverse sections through the nasal region of a 17 mm. specimen of *Caluromys philander*; 1, through the anterior ends of the vomers; 2, through the middle of the vomers. Harvard Emb. Coll., Series 707, Sections 245 and 228. $\times 39$ diam.

A, cartilaginous nasal septum; B, palate; C, vomer; D, palate process of premaxilla; E, vomeronasal organ of Jacobson.

its bearing on the homology of the mammalian vomer, induced me at this time to communicate the observation. Through the courtesy of Professor Minot I have been enabled recently to review the sections of the heads of three pouch-specimens of *Caluromys* (*Didelphys*) *philander* in which the paired origin of the vomer had been noted.

⁴Fuchs, Hugo. Ueber einen Rest des Parasphenoids bei einem rezenten Säugetiere. Anat. Anz., 1908, Bd. 32, p. 584-590.

In a specimen 18 mm. in length there is present a pair of vomers. These elongate ossifications lie approximately parallel with the ventral edge of the cartilaginous nasal septum and extend from its caudal end forward as far as the middle of the vomero-nasal cartilages of Jacobson. Here the septum is continuous ventrally with the palate, and in this region the vomers are connected with one another across the median line. The connection is a feeble one, consisting of a few delicate bony trabeculae which are present in only three of the sections. Beyond this place in the caudal direction, the septum and palate are separated by a space, so that the nasal cavities are in communication with each other from side to side. In this region the two vomers are seen to diverge as they are followed backward. Each bone for the most part is compressed, with sharp edges and surfaces directed more or less obliquely—ventrally toward its anterior end, ventrolaterally in the middle of its extent. Anterior to the vomers lie the paired palatine processes of the premaxillaries, adapted to the convex surfaces of the vomero-nasal cartilages. A parasphenoid ossification center was not observed.

The conditions here described were found to be essentially the same in the two other specimens examined which were from the same pouch.

The study of younger specimens may decide whether or not the bony bridges are secondary connections between a pair of independent vomerine ossifications. The large size and advanced state of ossification of the lateral parts is indicative of an earlier origin for them than for the insignificant median ossification. The osteogenetic tissue in which the vomers are developing is disposed in two lateral masses of mesenchyma, connected here and there by strands of the same tissue stretching across the middle line ventrad of the nasal septum. In sections passing through its anterior end, the vomerine ossification tract is found to be unpaired and to be situated beneath the nasal septum, from the perichondrium of which it is well separated. This median mass of osteogenetic tissue is, however, of small extent in comparison with the lateral masses of the tissue, and, except anteriorly, presents itself in strands and not as a continuous bed of mesenchyma.

Relics of the pair of plates which fuse to form the vomer in man are to be found in the alæ, projecting conspicuously at the caudal end of the bone. This suggests the probability of the alæ of the cat's vomer and of the vomers of other mammals having an origin from paired parts of the developing bone. The dumbbell-shaped bone of *Ornithorhynchus* is bifid caudally, a condition which seems to follow from the original paired state of this element. It is not, however, my intention at this time to enter into the question of the phylogeny of the vomer. The object of this communication is to record the paired origin of the vomer in a low mammal, in which class generally it must be insisted that further study of the development is necessary before the bone can be regarded as azygos in its beginning.

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ALMOST COMPLETE SUPPRESSION OF THE CUNEIFORM BONES OF A FOOT. AN INSTANCE OF VITAL READJUSTMENT.

BY

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WITH TWO FIGURES.

The following observation is reported not only because it is perhaps unique, but because it is a very striking instance of what might be called vital readjustment.

The foot is that of a white man aged 78, and apparently had not attracted any particular notice either before or during dissection. By an unfortunate mischance, the other foot has been lost sight of. The hands showed nothing remarkable beyond disease of one joint of a thumb. The foot consists—apart from the phalanges, which are free and apparently healthy—of the following pieces: the astragalus; the os calcis; the scaphoid, to which the bases of the first and second metatarsals are fused; the cuboid, with which are fused the third and fourth metatarsals and the distal dorsal portion of the external cuneiform; the fifth metatarsal. There is no trace of an internal cuneiform. The external cuneiform is represented by a small part of the dorsal aspect fused with the third metatarsal. It is very doubtful whether the middle cuneiform is represented at all, but it is possible that a small prominence in the sole may represent its distal end. This part of the tarsus is very pathological. The line of the joint between the astragalus and the scaphoid on the dorsal aspect is obscured by irregular bony growths, more or less interlocking, which probably interfered with motion, though the joint has persisted. The distal borders of the scaphoid cannot be made out accurately. This bone may be said to be amalgamated with the bases of the first and second metatarsals. Not only is there no sign of an internal or middle cuneiform bone on the dorsum, but the distance from the astragalus to the bases of the metatarsals seems if

anything smaller (certainly no greater) than that usually occupied by the scaphoid. On the inner aspect there is a great prolongation of the scaphoid into an uncommonly sharp tuberosity, which appears on the plantar aspect. The line of the joint with the first metatarsal may be followed in a general way, and there is no hint of any remnant of a cuneiform. A rounded ridge in the sole of the foot, from the base of the second metatarsal to the scaphoid, suggests vaguely a small part of a cuneiform, but nothing can be identified certainly.



The cuboid is distinctly shorter than a normal one, and is inextricably mixed with the bases of the third and fourth metatarsals. The reason for accepting a remnant of the external cuneiform bone is furnished by the position of the joint between these bony masses and the scaphoid. This joint, seen from the dorsum, is proximal to the apparent level of the second metatarsal, which would not be the case were the third metatarsal the only element. The joint of the fifth metatarsal shows some pathological changes, especially on

the dorsal aspect. It is much more oblique than is normal, and the tuberosity projects laterally to an uncommon degree. Accurate measurements of any of the metatarsals, with the exception of the fifth, are out of the question; but it is quite certain that this one is the longest of all. I believe that Pfitzner never observed this when making his studies of the relative lengths of the metatarsals. The illustrations show that the normal outlines of the foot have been remarkably well preserved, although the outer side of the foot is longer than it should be, and the tarsus forms too small a part of the whole. The most striking defect in the proportions is the great breadth of the foot. This is not caused by any error of articulation, for the nature of the pieces is such as to admit of practically no choice. The length of the articulated foot, measured from the back of the os calcis to the tip of the second toe, is a little over 21 cm., which is certainly small for a male foot. The greatest transverse breadth, at the proximal end of the phalanges, is a little more than 9 cm., which is abnormally large. It is a case of very advanced "flat foot." The illustrations make further description unnecessary.

An interesting question is—what caused this condition? That the foot is pathological is very clear; but nothing is more certain than that extraordinary anomalies are associated with pathology in a way that does not allow us to determine what is cause and what is effect. It does not seem possible that this condition is the consequence of a resection in early life. All we can say is that probably the internal and middle cuneiform bones, as well as the greater part of the external one, failed to develop; and that the organism, adapting itself to uncommon circumstances, attempted to preserve the general outline of the foot. The underdevelopment of the cuboid, and the obliquity of the joint between it and the fifth metatarsal are elements in this process.

All one has to do to appreciate how successful the effort at reparation has been is to put together the bones of a foot, leaving out the inner and middle cuneiforms and the greater part of the external one, and to compare the curves made by lines connecting the heads of the metatarsals or of the terminal phalanges with similar lines drawn on these illustrations. The more one thinks of it, the more

remarkable does it appear that so good a foot should have been formed under the circumstances. Through what agency has this been brought about? It seems to me that it is a clear instance of the act of the *vital principle* regulating growth, and repair; the same by which the amputated leg of a newt is reproduced. I incline to agree with Driesch that it should not be called a vital energy, for it is rather something regulating the energy. He would call it *entelechy*; a something "which bears the end in itself."¹ I find no fault with this, but prefer the other term.

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¹The Science and Philosophy of the Organism. By Hans Driesch, Ph.D. Gifford lectures, 1907-08, Vol. I, p. 144.

A COMPARATIVE STUDY OF THE LYMPHATICO- VENOUS COMMUNICATIONS IN ADULT MAMMALS.

I. PRIMATES, CARNIVORA, RODENTIA, UNGULATA AND MARSUPIALIA.

BY

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From the Laboratory of Comparative Anatomy, Princeton University.

WITH THREE TEXT-FIGURES AND TEN PLATES.

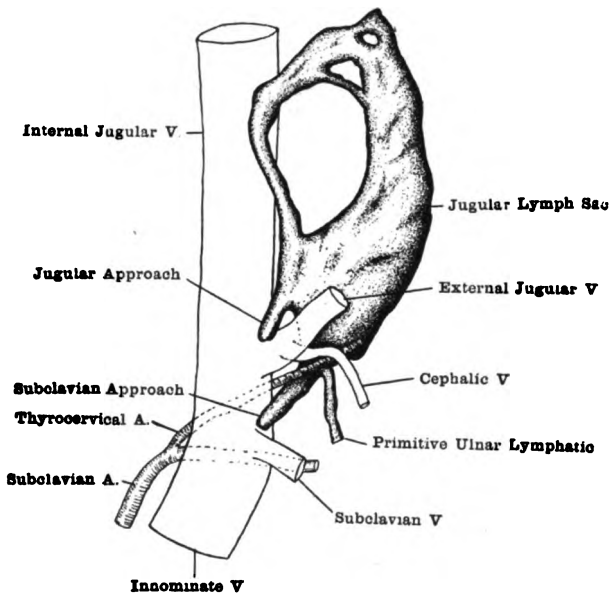
Huntington and McClure¹ have shown in the adult cat (*Felis domestica*) that the communication between the lymphatic system and the systemic veins may normally occur on each side of the body, within either one of two or within two typical districts. These two districts include, approximately, the angle of confluence formed by the union of the external and internal jugular veins (common jugular angle) and the angle of confluence formed by the union of the external jugular² and subclavian veins (jugulo-subclavian angle). An examination of a large number of adult cats proved conclusively that neither one of these two districts predominates as the place of communication between the lymphatics and the veins, but that either

¹Huntington and McClure, The Anatomy and Development of the Jugular Lymph Sacs in the Domestic Cat (*Felis domestica*). A paper read before The Association of American Anatomists in Chicago, in 1907, published in THE ANATOMICAL RECORD, Volume II, 1908, and soon to be published in a more complete form in The American Journal of Anatomy.

²This vein, strictly speaking, is a common jugular vein in the cat, but on account of its large size, as compared with the internal jugular, is usually spoken of as the external jugular vein of which the internal jugular is a tributary.

one of the two or both may serve equally in this capacity and for this reason both districts must be regarded as constituting normal points of communication between the lymphatics and the veins.

In following the development of the jugular lymph sacs in the embryonic cat Huntington and McClure were able to establish the basis upon which the duplex character of the lymphatico-venous communication in the adult rests. They found that the right as



TEXT-FIG. I.—A reconstruction of the left jugular lymph sac of a 11 mm. cat embryo (*Felis domestica*) showing the relations of the thyrocervical artery to the jugular and subclavian approaches through which the two typical adult communications are established between the lymphatics and the veins. Ventral view. Drawn from a reconstruction made by Huntington and McClure after the method of Born.

well as the left jugular lymph sac in the embryonic cat invariably presents two caudally directed processes or prolongations which they termed, respectively, the Jugular and Subclavian approaches (Text-fig. I). These two processes, on each side of the body, are directed

toward and approach the district of the common jugular angle and the district of the jugulo-subclavian angle, respectively, and they observed that it is through either one of the two or through both of these processes that the adult communication is established, a circumstance which accounts not only for the presence of a double communication in the adult cat but also establishes it as a character of morphological significance.

In view of the uniform conditions which prevail in the adult domestic cat concerning the presence of two typical districts of lymphatico-venous communication on each side of the body, the present writers have undertaken to determine to what extent this same uniformity may prevail in adult mammals in general.

We have thus far examined twenty-five (25) species distributed among fifty (50) adult mammals (24 primates, 4 carnivora, 12 rodents, 5 ungulates and 5 marsupials). These mammals were chosen at random from the Princeton Collection so that the conditions observed in them represent fairly well the average conditions which one might expect to find in any other similar group chosen in the same manner. The lymphatic system of each mammal was injected with gelatine and then carefully dissected out in the appropriate regions on each side of the body. A drawing to scale was made of each dissection to facilitate comparison. All of the figures in this paper therefore represent accurately the arrangement of the lymphatics as met with in the regions of communication and it is worthy of notice that the lymphatics present a marked variability, more so than the veins, not only in the different species examined but among different members of the same species. These variations will not be dealt with to any extent in the present paper except in so far as it becomes necessary to speak of them in connection with the communications which exist between the lymphatics and the veins.

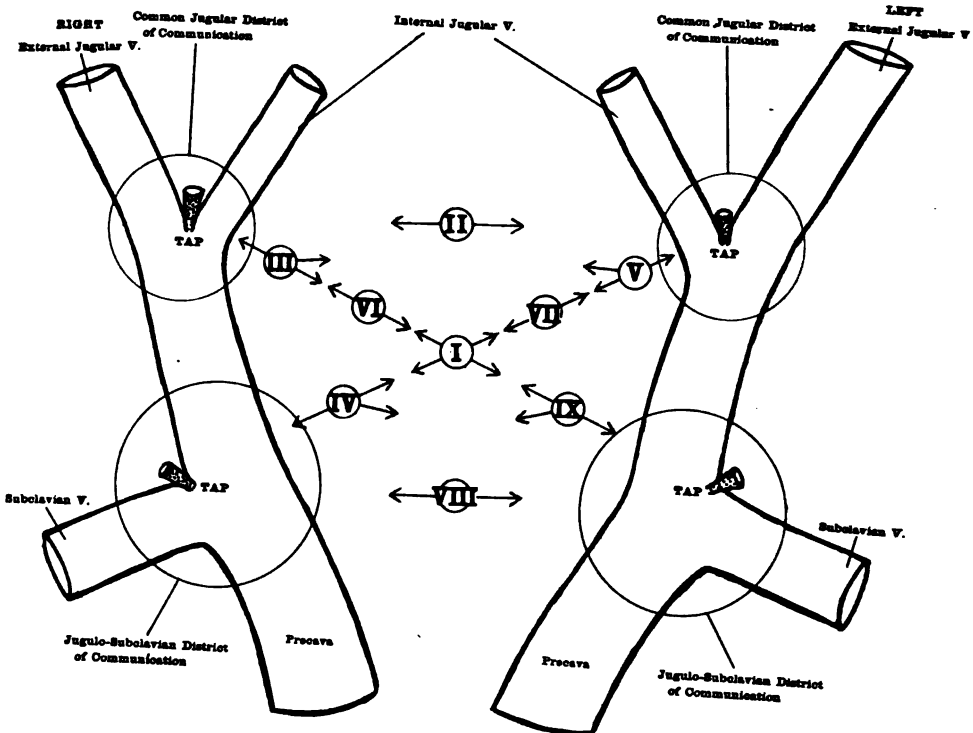
We may state at the beginning that we are warranted in drawing the conclusion from the adult mammals thus far examined that the lymphatic system normally communicates with the veins in these forms as in the adult cat, either at one of two or at two typical districts (common jugular and jugulo-subclavian districts) and that a communication at the two typical districts is the commonest of the

TABLE I.

	Right Side.							Left Side.						
	Primates.	Carnivora.	Rodentia.	Ungulata.	Marsupialia.	Total.	Percentage.	Primates.	Carnivora.	Rodentia.	Ungulata.	Marsupialia.	Total.	Percentage.
Communication at Common Jugular District only.....	8	1	3	3	1	16	32	7	0	3	2	0	12	24
Communication at Jugulo-Subclavian District only..	2	0	1	0	0	3	6	0	0	1	0	0	1	2
Communication at both Districts.....	14	3	8	2	4	31	62	17	4	8	3	5	37	74

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body are taken into consideration. Since a communication may be normally established in one of three ways on each side of the body, it is evident, when both sides of the body are considered, that the lymphatico-venous communications may occur in nine possible combinations and that each combination may be regarded as a type of



TEXT-FIG. II. A diagram of the precaval system of veins showing the two typical districts of lymphatico-venous communication on each side of the body and the nine possible combinations in which communications may occur when both sides of the body are taken into consideration. Ventral view.

communication which characterizes the lymphatico-venous communication of a particular individual.

Each of the nine possible combinations is indicated in Text-fig. II by a series of arrows which radiate from a small circle enclosing the Roman numeral (I-IX) applied to the combination and is also

TABLE II.

SHOWING THE NINE POSSIBLE COMBINATIONS (TYPES OF LYMPHATICO-VEINOUS COMMUNICATION) IN WHICH LYMPHATICO-VEINOUS COMMUNICATIONS MAY BE NORMALLY ESTABLISHED IN AN INDIVIDUAL WHEN BOTH SIDES OF THE BODY ARE TAKEN INTO CONSIDERATION.

Type	Right Side		Left Side	
	Common Jugular District.	Jugulo-Sub-clavian District.	Common Jugular District.	Jugulo-Sub-clavian District.
I.	TAP	TAP	TAP	TAP
II.	TAP		TAP	
III.	TAP		TAP	TAP
IV.		TAP	TAP	TAP
V.	TAP	TAP	TAP	
VI.	TAP			TAP
VII.		TAP	TAP	
VIII.		TAP		TAP
IX.	TAP	TAP		TAP

The word TAP, under the district designated, indicates the presence of a communication at this district between the lymphatics and the veins.

TABLE III.

SHOWING THE DISTRIBUTION AMONG THE FIFTY MAMMALS EXAMINED OF THE NINE POSSIBLE COMBINATIONS OR TYPES OF LYMPHATICO-VEINOUS COMMUNICATION WHICH MAY BE NORMALLY ESTABLISHED IN AN INDIVIDUAL.

Type.	Primates.	Carnivora.	Rodentia.	Ungulata.	Marsupialia.	Number and Percentage of Individuals.
I.	12	3	8	2	4	29 or 58 per cent.
II.	5	0	2	2	0	9 or 18 " "
III.	3	1	0	1	1	6 or 12 " "
IV.	2	0	0	0	0	2 or 4 " "
V.	2	0	0	0	0	2 or 4 " "
VI.	0	0	1	0	0	1 or 2 " "
VII.	0	0	1	0	0	1 or 2 " "
VIII.	0	0	0	0	0	0
IX.	0	0	0	0	0	0
Total	24	4	12	5	5	50

shown in Table II, in which the word TAP indicates the presence of a communication under the district of communication designated.

The following figures illustrate examples of the different types of lymphatico-venous communication as met with among the fifty mammals examined:

TYPE I, Figs. 6, Pl. III (*Papio porcarius*), 16, Pl. VI (*Putorius vison*), 22, Pl. VII (*Cavia porcellus*), 26, Pl. VIII (*Sus scrofa domestica*) and 31, Pl. X (*Didelphys virginiana*).

TYPE II, Figs. 12, Pl. V (*Anthropopithecus troglodytes*), 21, Pl. VII (*Lepus cuniculus*) and 27, Pl. IX (*Sus scrofa domestica*).

TYPE III, Figs. 5, Pl. II (*Papio anubis*), 15, Pl. VI (*Canis familiaris*) and 30, Pl. IX (*Didelphys virginiana*).

TYPE IV, Figs. 4, Pl. II (*Papio anubis*) and 1, Pl. I (*Nycticebus tardigradus*).

TYPE V, Figs. 13, Pl. V (*Anthropopithecus troglodytes*)³ and 8, Pl. III (*Macacus rhesus*).

TYPE VI, Fig. 19, Pl. VII (*Lepus cuniculus*).

TYPE VII, Fig. 20, Pl. VII (*Lepus cuniculus*).

As shown in Table III the lymphatico-venous communication of every mammal examined fell within one of these nine combinations (Types I-IX). This circumstance, together with the fact that in twenty-nine (29) individuals or fifty-eight (58) per cent of those examined (Table III) the communication occurred on both sides of the body at the two typical districts of communication, and that this type of communication was commonly met with in each of the five orders of mammals examined (Type I, see Text-fig. II and Table III), indicates that the embryonic basis for the establishment of two typical communications on each side of the body must be fundamentally and potentially the same in the fifty mammals examined by us as that described by Huntington and McClure for the domestic cat. Although our present deductions do not lead us beyond a consideration of the conditions observed in the fifty mammals (25 species) it is evident, if this conception of two primary and

³It is significant to note in the two chimpanzees examined, in which the precaval system of veins resembles that in man, that Types II and V are represented.

typical districts of communication on each side of the body can be generalized for mammals as a whole, that a consistent description of the adult lymphatico-venous communications should rest upon a morphological interpretation of their development, and not upon the ill-defined and variable conditions which are at present described in works of anatomy as constituting the points at which the lymphatics communicate with the veins.

It is interesting to note that Type VIII, in which a communication occurs on both sides of the body only at the jugulo-subclavian district (angle of confluence formed by the union of the external jugular and subclavian veins), a region commonly assigned by anatomists as the point at which the thoracic and right lymphatic ducts tap the veins, *was not met with in a single one of the mammals examined.*

As shown in Table I and Table III, when a communication is present on each side of the body at only one of the two typical districts it is usually found at the common jugular (Type II) and not at the jugulo-subclavian district.

The assignment of the jugulo-subclavian angle as the point at which in general the lymphatics communicate with the veins in the adult, appears to us to be a correct interpretation for the cat and for the mammals we have thus far examined, only in the sense that the two districts of confluence formed by the union of the external and internal jugular and by the union of the external jugular and subclavian veins, respectively, be regarded as constituting a single district of communication.

Tables IV to VIII, inclusive, show in tabulated form the different species of mammals examined by us as well as the *type* of lymphatico-venous communication presented by each individual.⁴

The word TAP in each column, under the district designated, indicates the presence of a communication at this district between the lymphatics and the veins, while the absence of the word TAP indicates that a communication is wanting.

The number after the sex sign of each species indicates the cata-

⁴The nomenclature of the species mentioned in this paper follows that given in Trouessart's *Catalogus Mammalium*, *Quinquennale Supplement*, 1904.

TABLE IV.—PRIMATES.

	Type.	Right Side.		Left Side.	
		Common Jugular District.	Jugulo-Subclavian District.	Common Jugular District.	Jugulo-Subclavian District.
<i>Nycticebus tardigradus</i> ♀ 2374 (Fig. 1, Pl. I.)....	IV		TAP	TAP	TAP
<i>Callithrix jacchus</i> ♀ 2457.....	I	TAP	TAP	TAP	TAP
<i>Cebus capucinus</i> ♀ 2481 (Fig. 2, Pl. I.)...	I	TAP	TAP	TAP	TAP
<i>Cebus hypoleucus</i> ♀ 2472.....	I	TAP	TAP	TAP	TAP
<i>Ateles hybridus</i> ♂ 2433.....	II	TAP		TAP	
<i>Ateles hybridus</i> ♂ 2435.....	III	TAP		TAP	TAP
<i>Ateles vellerosus</i> ♀ 2476 (Fig. 3, Pl. I.)....	I	TAP	TAP	TAP	TAP
<i>Papio anubis</i> ♀ 2368 (Fig. 4, Pl. II.)..	IV		TAP	TAP	TAP
<i>Papio anubis</i> ♂ 2432 (Fig. 5, Pl. II.)..	III	TAP		TAP	TAP
<i>Papio porcarius</i> ♂ 2453 (Fig. 6, Pl. III.)..	I	TAP	TAP	TAP	TAP
<i>Papio porcarius</i> ♂ 2460.....	I	TAP	TAP	TAP	TAP
<i>Macacus speciosus</i> ♂ 2376 (Fig. 7, Pl. III.)..	II	TAP		TAP	
<i>Macacus rhesus</i> ♀ 2487 (Fig. 8, Pl. III.)..	V	TAP	TAP	TAP	
<i>Macacus nemestrinus</i> ♂ 2458 (Fig. 9, Pl. IV.)..	II	TAP		TAP	
<i>Macacus nemestrinus</i> ♀ 2459.....	I	TAP	TAP	TAP	TAP
<i>Macacus nemestrinus</i> ♂ 2461.....	III	TAP		TAP	TAP
<i>Macacus nemestrinus</i> ♂ 2483.....	I	TAP	TAP	TAP	TAP
<i>Cercocebus fuliginosus</i> ♀ 2394.....	II	TAP		TAP	
<i>Cercopithecus callitrichus</i> ♂ 2434.....	I	TAP	TAP	TAP	TAP
<i>Cercopithecus callitrichus</i> ♂ 2464 (Fig. 10, Pl. IV.)..	I	TAP	TAP	TAP	TAP
<i>Cercopithecus callitrichus</i> ♀ 2477 (Fig. 11, Pl. V.)..	I	TAP	TAP	TAP	TAP
<i>Cercopithecus callitrichus</i> ♂ 2478.....	I	TAP	TAP	TAP	TAP
<i>Anthropopithecus troglodytes</i> ♂ 2467 (Fig. 12, Pl. V.)..	II	TAP		TAP	
<i>Anthropopithecus troglodytes</i> ♀ 2468 (Fig. 13, Pl. V.)..	V	TAP	TAP	TAP	

TABLE V.—CARNIVORA.

	Type.	Right Side.		Left Side.	
		Common Jugular District.	Jugulo-Subclavian District.	Common Jugular District.	Jugulo-Subclavian District.
<i>Felis domestica</i> ♂ 2452 (Fig. 14, Pl. V.)..	I	TAP	TAP	TAP	TAP
<i>Canis familiaris</i> ♀ 2451 (Fig. 15, Pl. VI.)..	III	TAP		TAP	TAP
<i>Putorius vison</i> ♂ 2384 (Fig. 16, Pl. VI.)..	I	TAP	TAP	TAP	TAP
<i>Mephitis putida</i> ♂ 2362 (Fig. 17, Pl. VI.)..	I	TAP	TAP	TAP	TAP

TABLE VI.—RODENTIA.

	Type.	Right Side.		Left Side.	
		Common Jugular District.	Jugulo-Subclavian District.	Common Jugular District.	Jugulo-Subclavian District.
<i>Lepus cuniculus</i> ♂ 2363 (Fig. 18, Pl. VII.)..	I	TAP	TAP	TAP	TAP
<i>Lepus cuniculus</i> ♂ 2364 (Fig. 19, Pl. VII.)..	VI	TAP			TAP
<i>Lepus cuniculus</i> ♂ 2366 (Fig. 20, Pl. VII.)..	VII		TAP	TAP	
<i>Lepus cuniculus</i> ♂ 2367	I	TAP	TAP	TAP	TAP
<i>Lepus cuniculus</i> ♀ 2431 (Fig. 21, Pl. VII.)..	II	TAP		TAP	
<i>Cavia porcellus</i> ♂ 2359	I	TAP	TAP	TAP	TAP
<i>Cavia porcellus</i> ♂ 2360 (Fig. 22, Pl. VII.)..	I	TAP	TAP	TAP	TAP
<i>Fiber zibethicus</i> ♂ 2361	II	TAP		TAP	
<i>Fiber zibethicus</i> ♂ 2365 (Fig. 23, Pl. VIII.)..	I	TAP	TAP	TAP	TAP
<i>Fiber zibethicus</i> ♀ 2395	I	TAP	TAP	TAP	TAP
<i>Marmota monax</i> ♀ 2469 (Fig. 24, Pl. VIII.)..	I	TAP	TAP	TAP	TAP
<i>Sciurus hudsonius</i> ♀ 2466 (Fig. 25, Pl. VIII.)..	I	TAP	TAP	TAP	TAP

TABLE VII.—UNGULATA.

	Type.	Right Side.		Left Side.	
		Common Jugular District.	Jugulo-Subclavian District.	Common Jugular District.	Jugulo-Subclavian District.
<i>Sus scrofa domestica</i> ♀ 2436 (Fig. 26, Pl. VIII.)	I	TAP	TAP	TAP	TAP
<i>Sus scrofa domestica</i> ♀ 2437 (Fig. 27, Pl. IX.)	II	TAP		TAP	
<i>Sus scrofa domestica</i> ♀ 2438	III	TAP		TAP	TAP
<i>Sus scrofa domestica</i> ♂ 2439	II	TAP		TAP	
<i>Sus scrofa domestica</i> ♀ 2441 (Fig. 28, Pl. IX.)	I	TAP	TAP	TAP	TAP

TABLE VIII.—MARSUPIALIA.

	Type	Right Side.		Left Side.	
		Common Jugular District.	Jugulo-Subclavian District.	Common Jugular District.	Jugulo-Subclavian District.
<i>Didelphys virginiana</i> ♂ 2388 (Fig. 29, Pl. IX.)	I	TAP	TAP	TAP	TAP
<i>Didelphys virginiana</i> ♀ 91	I	TAP	TAP	TAP	TAP
<i>Didelphys virginiana</i> ♀ 96 (Fig. 30, Pl. IX.)	III	TAP		TAP	TAP
<i>Didelphys virginiana</i> ♀ 90	I	TAP	TAP	TAP	TAP
<i>Didelphys virginiana</i> ♂ 51 (Fig. 31, Pl. X.)	I	TAP	TAP	TAP	TAP

logue number of the individual in the Princeton Collection. The individuals figured in this paper are also designated in these tables.

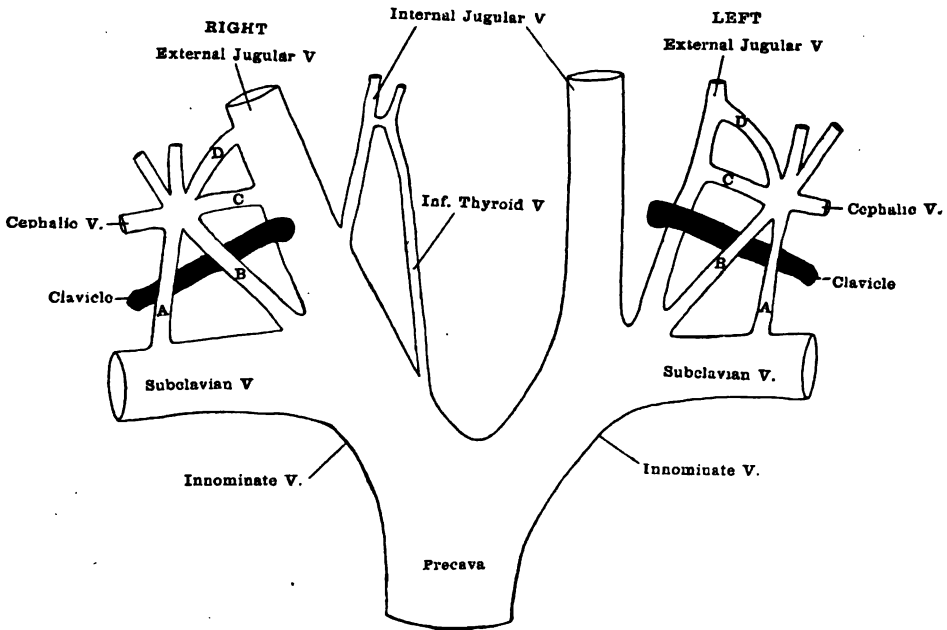
Before proceeding to a detailed description of the lymphatico-venous communications observed in the fifty mammals, we will first consider the general character of the two typical districts of lymphatico-venous communication.

Text-fig. III is a composite diagram of the preceaval system of veins constructed on the basis of the conditions actually observed in the fifty mammals under consideration and should be constantly referred to in connection with the following description of the external and internal jugular and cephalic veins.

1. The External and Internal Jugular Veins.

The external jugular may be larger (Fig. 16, Pl. VI) or smaller (Fig. 12, Pl. V) than the internal jugular vein, or, of practically the same size (Fig. 5, Pl. II).

The common jugular district of lymphatico-venous communication may lie on the same level and in close proximity to the jugulo-sub-



TEXT-FIG. III.—A composite diagram of the precaval system of veins constructed on the basis of the conditions observed in the fifty mammals examined and with especial reference to the relations of the two typical districts of lymphatico-venous communication to each other. Ventral view.

clavian district as in *Papio porcarius* (Fig. 6, Pl. III) or, as is usually the case in the domestic cat, it may lie somewhat cranial to the jugulo-subclavian district as shown on the right side of Fig. 14 (Pl. V) and on the right side of Text-fig. III. In either case, however, the two districts of communication are separated from each other by the external jugular vein.

In the domestic cat the internal jugular vein at times gives up

its original connection with the external jugular and then drains into the innominate through the inferior thyroid vein. In a case observed by us in which this occurred (Fig. 14, Pl. V, left side), the common jugular district of lymphatico-venous communication was not transferred to the new angle of confluence formed by the union of the inferior thyroid and innominate veins but remained on the external jugular at the point where, as on the right side of the same individual (Fig. 14, Pl. V, right side), the internal jugular normally joins the external jugular vein.

2. The External Jugular and Cephalic Veins.

As is well known, the cephalic vein presents considerable variability in its relations to the external jugular and subclavian veins, not only in mammals in general but even upon opposite sides of the same individual. The complex of vessels connected with the external jugular and subclavian veins on both sides of Text-fig. III, represents a composite picture of the conditions observed in the fifty mammals examined by us and is an attempt to explain, from the standpoint of comparative anatomy, the variable conditions of the cephalic vein, as well as those sometimes presented by the external jugular, the transverse scapular and deep transverse scapular veins. One might infer from a study of comparative anatomy that this complex of veins may possibly represent a ground-plan arrangement and that the elements of which it is composed are capable of serving in variable capacities, not only in different individuals, but even upon opposite sides of the same individual.

In explanation of the basis upon which the above observations are made the following description of the conditions actually met with, to be compared with the diagram (Text-fig. III), is given.

One of the commonest terminations of the cephalic vein met with is its connection with the external jugular, as in *Felis domestica* (Fig. 14, Pl. V), *Canis familiaris* (Fig. 15, Pl. VI), *Putorius vison* (Fig. 16, Pl. VI), *Fiber zibethicus* (Fig. 23, Pl. VIII), *Cavia porcellus* (Fig. 22, Pl. VII), and *Sus scrofa domestica* (Fig. 26, Pl. VIII), where it is commonly established through the vessel C or D in Text-fig. III. It may be formed, as in *Macacus rhesus* (Fig. 8,

Pl. III), *Cercopithecus callitrichus* (Fig. 11, Pl. V) and *Cebus capucinus* (Fig. 2, Pl. I), through the retention of the vessels B and D in Text-fig. III, as is also the case in *Didelphys virginiana* (Fig. 31, Pl. X, left side). It may also be formed in *Didelphys virginiana* (Fig. 31, Pl. X, right side), as is more commonly the case,⁵ through the retention of the vessels A and D in Text-fig. III. In *Sciurus hudsonius* (Fig. 25, Pl. VIII) it may be formed through the retention of the vessel C in Text-fig. III, but vessels B and D may also be present where they, together with the external jugular vein, form a loop or ring through which the clavicle passes. In one specimen of *Ateles vellerosus* examined (Fig. 3, Pl. I), in which there is an asymmetrical arrangement of the veins on opposite sides, the cephalic vein is formed through the retention of the vessel A in Text-fig. III on the right side and by the vessel B on the left. Although the conditions observed in *Ateles* are probably abnormal, they serve as a good general illustration of the variability manifested by termination of the cephalic vein.

The elements which compose the complex of veins ordinarily entering into the formation of the cephalic also appear to be capable of functioning as the terminals of veins other than the cephalic. For example, in *Lepus cuniculus* (Fig. 20, Pl. VII) the transverse scapular vein appears to have been established through the vessel B in Text-fig. III which in *Ateles vellerosus* (Fig. 3, Pl. I, left side) and in part in *Macacus rhesus* (Fig. 8, Pl. III) constitutes the terminal of the cephalic vein. Also in *Marmota monax* (Fig. 24, Pl. VIII), as shown by its relation to the clavicle, the external jugular vein has largely transferred its drainage from its conventional pathway to the vessel B in Text-fig. III which now functions as the chief terminal of the external jugular vein.

At first sight one might regard the boundaries of the two typical districts of lymphatico-venous communication as being fundamentally modified in accordance with the variations presented by the veins in the region of the lymphatico-venous communications. Such does

⁵C. F. W. McClure, A Contribution to the Anatomy and Development of the Venous System in *Didelphys marsupialis*. Part I, Anatomy. Amer. Jour. of Anatomy, Vol. II, 1903 (see Fig. II, p. 377).

not appear to be the case, however, since the primary relations established by the union of the external and internal jugulars and by the external jugular and subclavian veins, respectively, definitely mark out the two typical districts of communication as evidenced by the constancy with which communications occur in connection with these districts, regardless of the variation presented by the veins.

We pass now to a consideration of the general character of the lymphatico-venous communications as met with in the fifty mammals examined.

When a communication occurred on either side, at either one of the two typical districts, it was usually single in character as shown in Table IX. In only a few instances were the lymphatics found to communicate with the veins within either of the two typical districts by more than one opening. A multiple communication between the lymphatics and the veins was found at the common jugular district of communication in *Ateles vellerosus* (Fig. 3, Pl. I, right side), in *Cercopithecus callitrichus* (Fig. 11, Pl. V, both sides), in *Felis domestica* (Fig. 14, Pl. V, right side), in *Macacus nemestrinus* (Fig. 9, Pl. IV, both sides) and the the jugulo-subclavian district of communication in *Canis familiaris* (Fig. 15, Pl. VI, left side) and in *Cercopithecus callitrichus* (Fig. 10, Pl. IV, right side).

As shown in the following table, only twelve (12) instances of a multiple communication at the two typical districts were met with and it occurred more frequently on the right than on the left side of the body.

One hundred and seventy-eight (178) points of communication between the lymphatics and the veins were observed by us on both sides of the body in the fifty mammals under consideration (89 on each side). Of these, one hundred and forty-two (142) were found either at the angles of confluence formed by the union of the external and internal jugular and by the union of the external jugular and subclavian veins, respectively, or were included within these two angles, as illustrated by Figs. 12, Pl. V, 13, Pl. V (*Anthropopithecus troglodytes*), 3, Pl. I (*Ateles vellerosus*), 7, Pl. III

(*Macacus speciosus*), 8, Pl. III (*Macacus rhesus*), 1, Pl. I (*Nycticebus tardigradus*), 4, Pl. II, 5, Pl. II (*Papio anubis*), 22, Pl. VII (*Cavia porcellus*), 19, Pl. VII, 20, Pl. VII, 21, Pl. VII (*Lepus cuniculus*), 24, Pl. VIII (*Marmota monax*), 25, Pl. VIII (*Sciurus hudsonius*) and 27, Pl. IX (*Sus scrofa domestica*).

TABLE IX.

SHOWING THE PREDOMINANCE OF A SINGLE OVER A MULTIPLE COMMUNICATION AT EACH OF THE TWO TYPICAL DISTRICTS OF LYMPHATICO-VEIN COMMUNICATION.

	Right Side.						Left Side.					
	Primates.	Carnivora.	Rodentia.	Ungulata.	Marsupialia.	Total.	Primates.	Carnivora.	Rodentia.	Ungulata.	Marsupialia.	Total.
Single Communication at Common Jugular District	19	3	11	3	5	41	22	4	11	5	5	47
Multiple Communication at Common Jugular District	3	1		2		6	2					2
Communication Wanting at Common Jugular District	2		1			3			1			1
Total	24	4	12	5	5	50	24	4	12	5	5	50
Single Communication at Jugulo-Subclavian District	13	3	9	2	4	31	17	3	9	3	5	37
Multiple Communication at Jugulo-Subclavian District	3					3		1				1
Communication Wanting at Jugulo-Subclavian District	8	1	3	3	1	16	7		3	2		12
Total	24	4	12	5	5	50	24	4	12	5	5	50

Three (3) points of communication met with did not fall either within the angle of confluence formed by the union of the external and internal jugular nor within the angle formed by the union of the external jugular and subclavian veins, but, as in Figs. 2, Pl. I (*Cebus capucinus*, right side), 28, Pl. IX (*Sus scrofa domestica*,

left side) and 14, Pl. V (*Felis domestica*, right side), they occurred on the veins slightly caudal to the angle of venous confluence (caudal to the common jugular angle in *Cebus* and *Felis*, and to the jugulo-subclavian angle in *Sus*).

Also, in addition to these three points of communication just mentioned, thirty-three (33) others were met with which did not fall within the common jugular nor jugulo-subclavian angles but which were dorsally or ventrally situated on the veins in close proximity to either one of the two of these angles.

Of these dorsal and ventral communications between the lymphatics and the veins, the former proved to be the more common of the two.

A dorsal communication between the lymphatics and the veins on both sides of the body at the common jugular district of communication is shown in Figs. 15, Pl. VI (*Canis familiaris*) and 17, Pl. VI (*Mephitis putida*). A dorsal communication between the lymphatics and the veins on the right side of the body at the common jugular district of communication is shown in Figs. 10, Pl. IV (*Cercopithecus callitrichus*) and 9, Pl. IV (*Macacus nemestrinus*) and at the jugulo-subclavian district of communication in Fig. 23. Pl. VIII (*Fiber zibethicus*). A dorsal communication between the lymphatics and the veins on the left side of the body at the jugulo-subclavian district of communication is shown in Figs. 29, Pl. IX (*Didelphys virginiana*) and 26, Pl. VIII (*Sus scrofa domestica*).

A ventral communication between the lymphatics and the veins on both sides of the body at the common jugular district of communication is shown in Figs. 11, Pl. V (*Cercopithecus callitrichus*) and at the jugulo-subclavian district in Fig. 17, Pl. VI (*Mephitis putida*). A ventral communication between the lymphatics and the veins on the left side of the body at the jugulo-subclavian district of communication is shown in Fig. 6, Pl. III (*Papio porcarius*) and on the right side of the body in Fig. 11, Pl. V (*Cercopithecus callitrichus*).

In consideration of the large number of communications observed within the common jugular and jugulo-subclavian angles (142), the presence of these thirty-six apparently variant forms appears to

find its explanation in the circumstances that the communications established between the embryonic jugular lymph sac and the veins are not confined exclusively within these two angles of venous confluence but may vary about the same in a sphere which we have designated a district of communication (Text-figs. II and III). The circumstance that angle, dorsal, and ventral communications may be found in the same individual, in which they hold definite relations to either one of the two typical angles of venous confluence and that, in some cases, dorsal and ventral communications are alone present (Fig. 17, Pl. VI), seems conclusive evidence that all of the points of communication observed by us between the lymphatics and the veins must have been established in the embryo in fundamentally the same manner as in the domestic cat and in definite relation to two typical districts of communication.

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EXPLANATION OF PLATES I TO X.

Figs. 1 to 31, inclusive, were drawn to scale from dissections of adult mammals and represent *ventral* views of the veins and lymphatic vessels in the regions where the lymphatics communicate with the veins.

The veins are drawn in outline, the lymphatics are colored. The word TAP indicates a point at which the lymphatics communicate with the systemic veins.

The name of the species represented is given under each figure while a complete list of the mammals dissected and studied in connection with this paper may be found in Tables IV, V, VI, VII and VIII.

LYMPHATICO-VENOUS COMMUNICATIONS.

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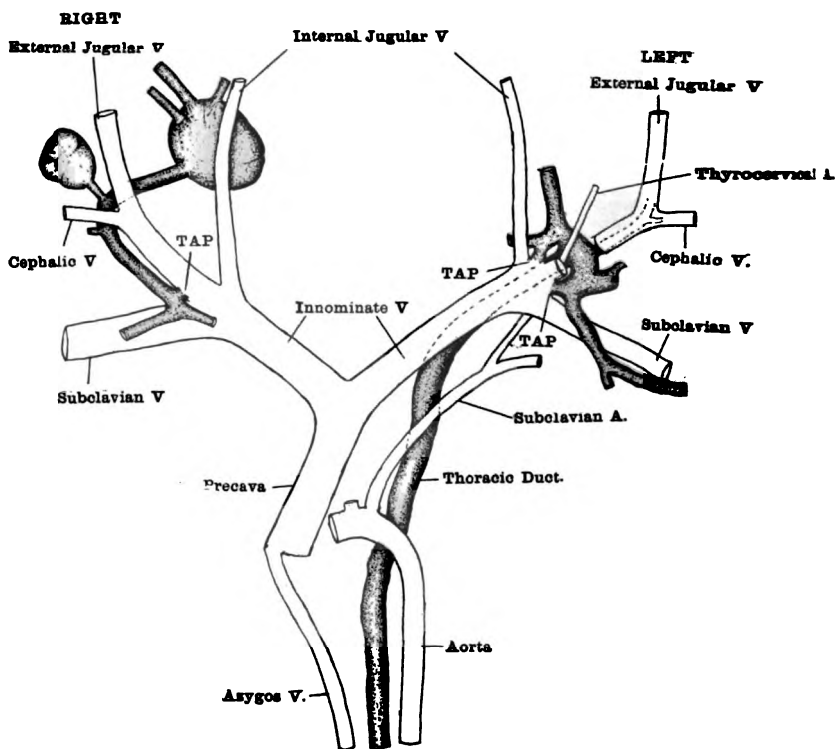


FIG. 1 (TYPE IV)

Slow Loris ♀

Nycticebus tardigradus, Linn.

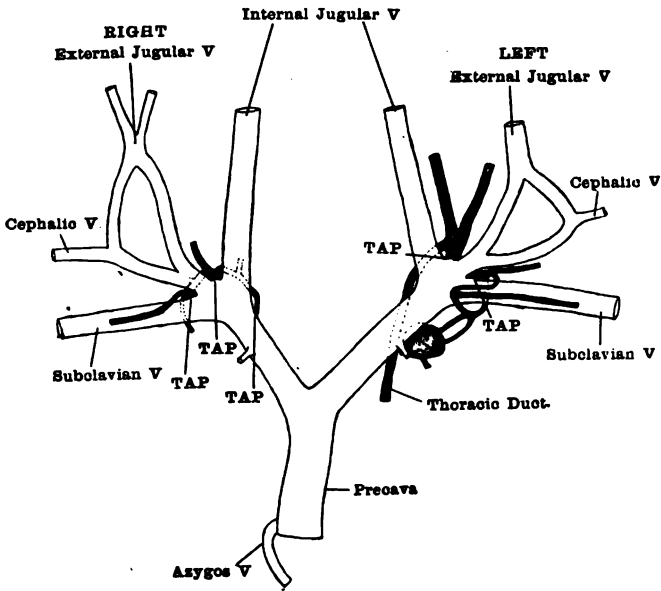


FIG. 2 (TYPE I)
Capuchin Monkey ♀
Cebus capucinus, Linn.

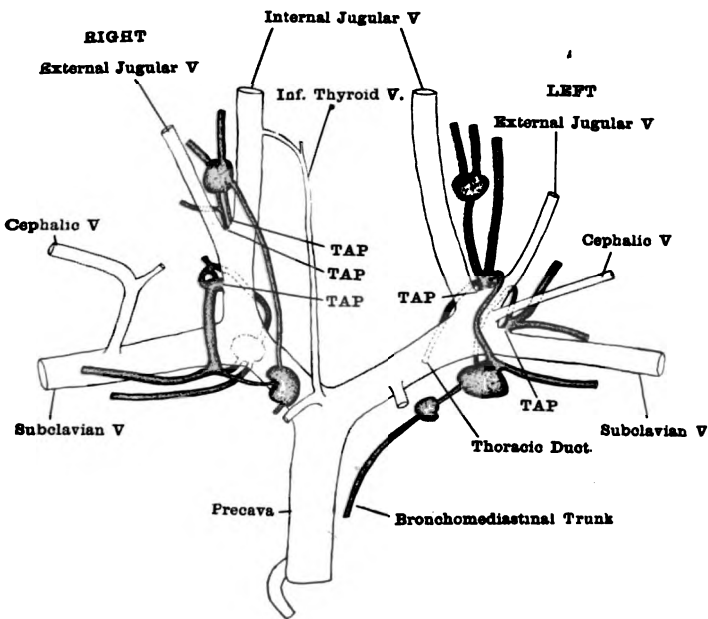


FIG. 3 (TYPE I)
Spider Monkey ♀
Ateles vellerosus, Gray

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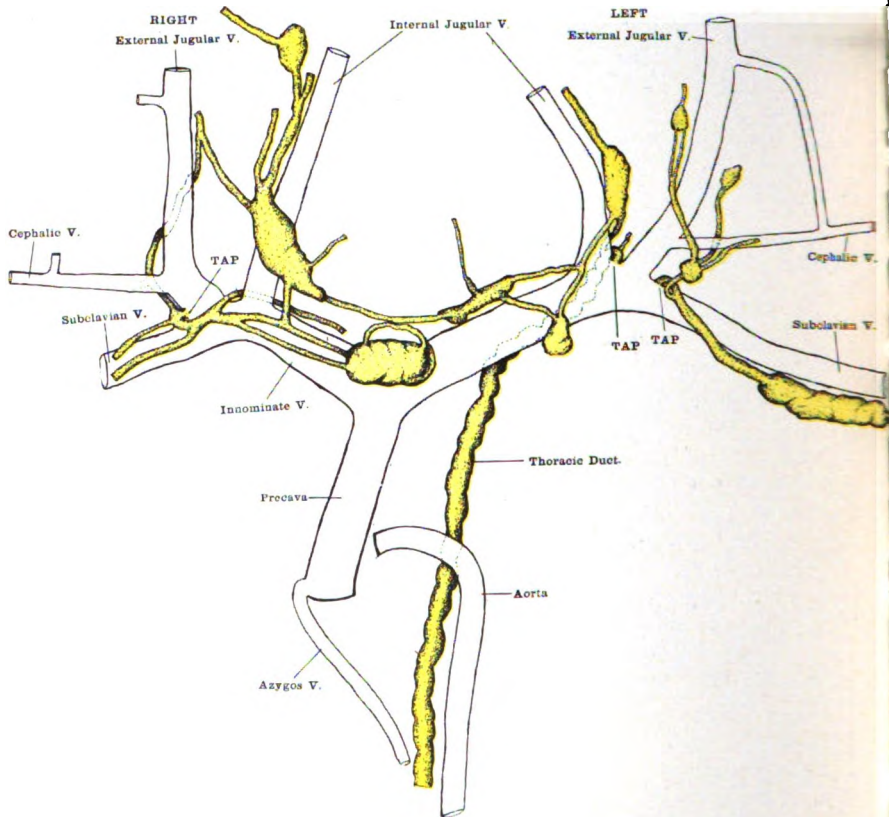


FIG. 4 (TYPE IV)
Anubis Baboon ♀
Papio anubis F. Cuv.

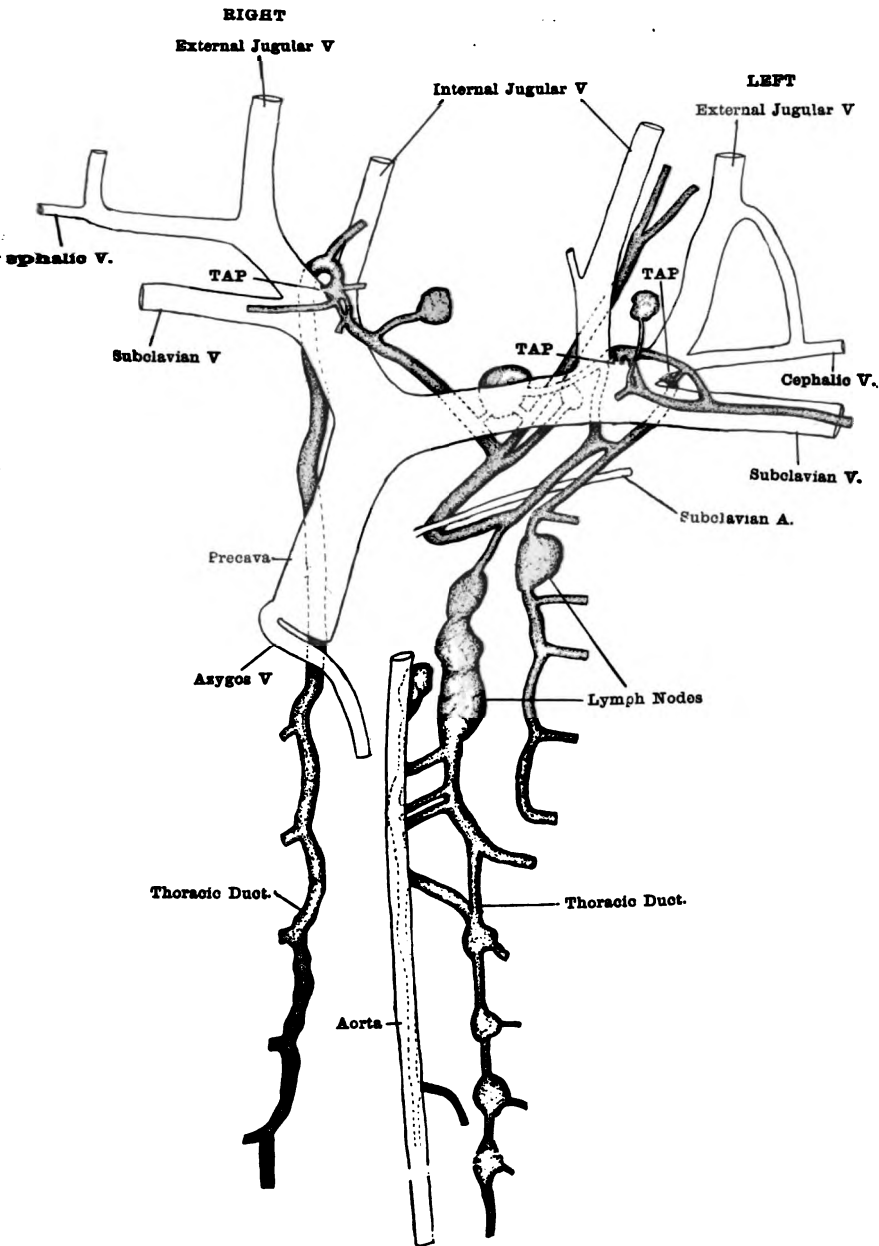


FIG. 5 (TYPE III)
Anubis Baboon ♂
Papio anubis, F. Cuv.

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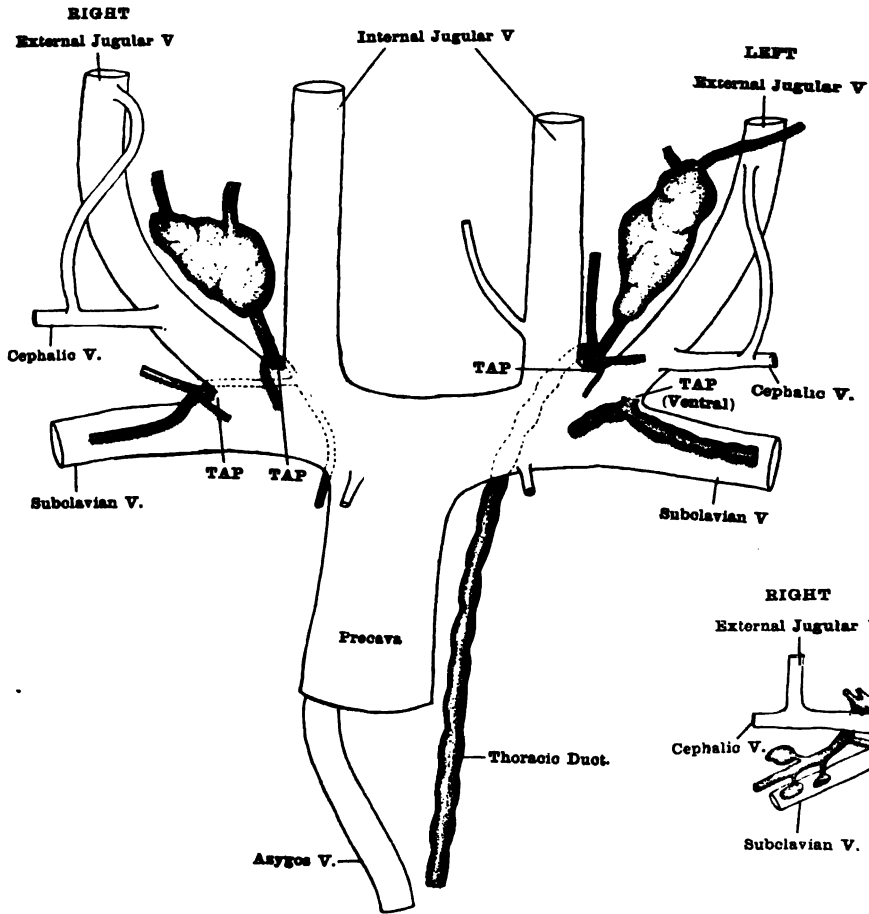


FIG. 6 (TYPE I)
 Chacama Baboon ♂
Papio porcarius. Bodd.

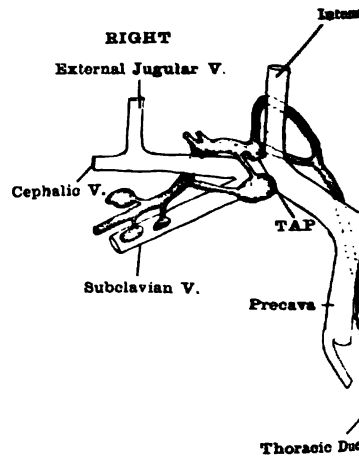


FIG. 7
 Japanese
Macacus ♂

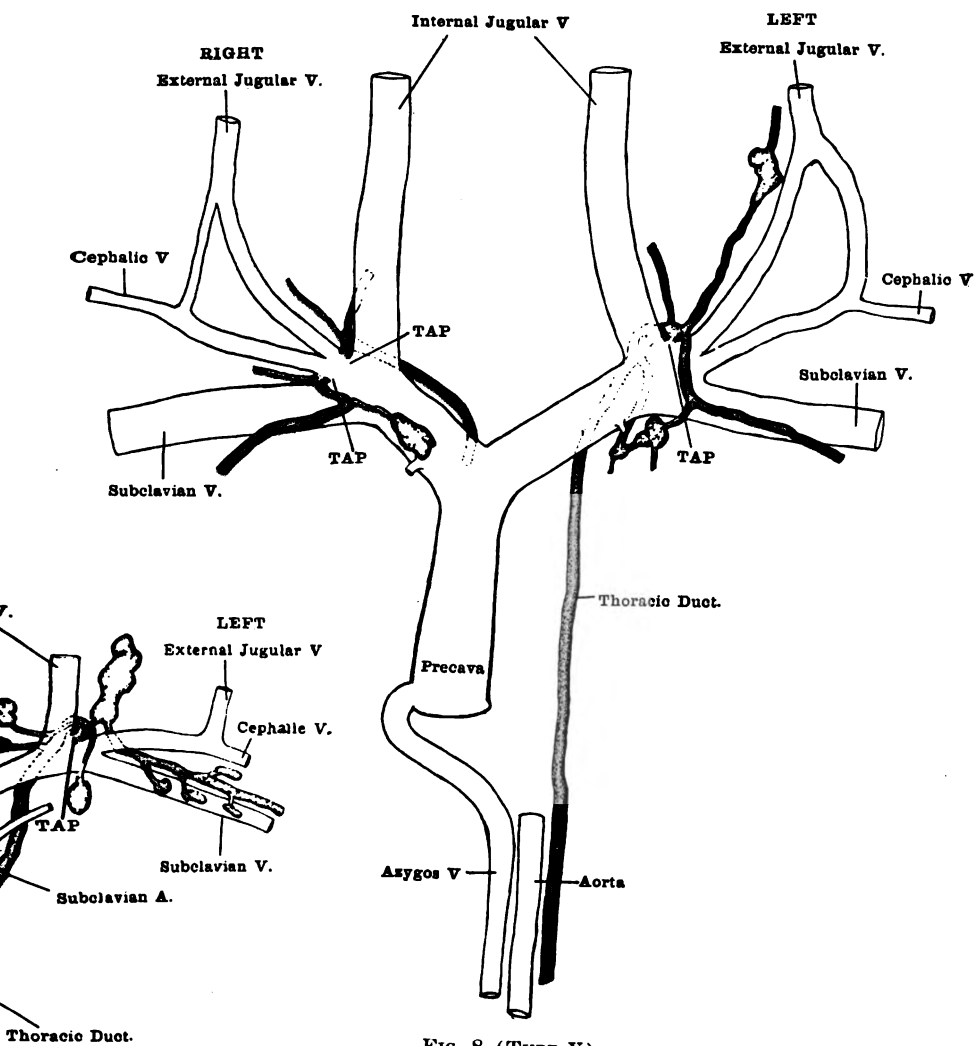


FIG. 8 (TYPE V)
Rhesus Monkey ♀
Macacus rhesus, Audebert

II)
♂
8, Cuv.

LYMPHATICO-VENOUS COMMUNICATIONS.

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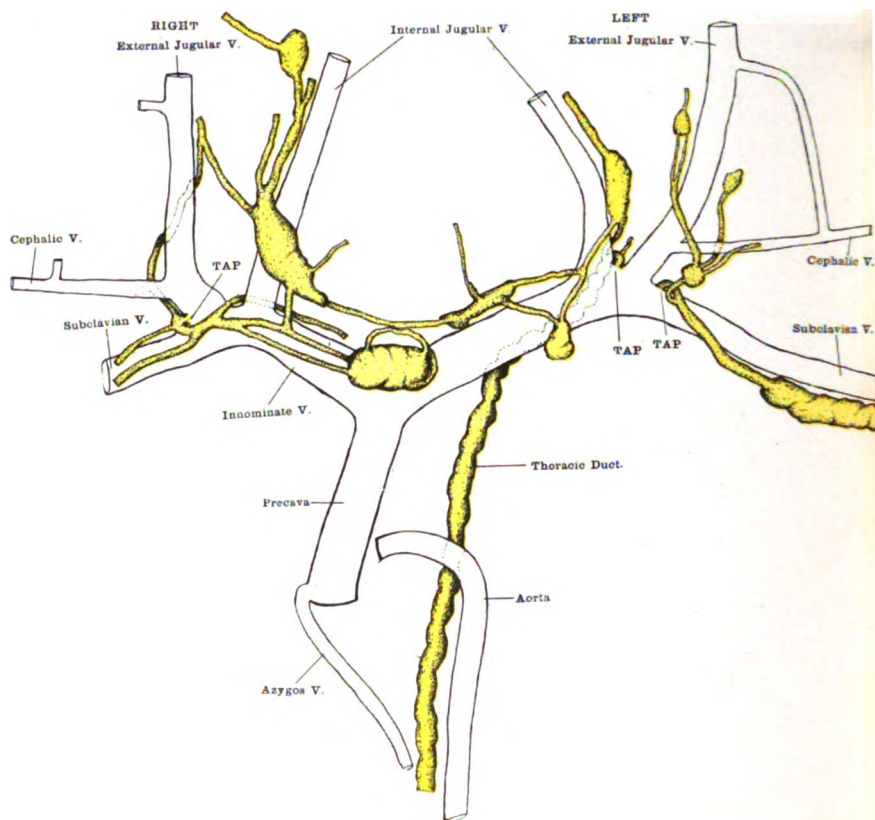


FIG. 4 (TYPE IV)
Anubis Baboon ♀
Papio anubis F. Cuv.

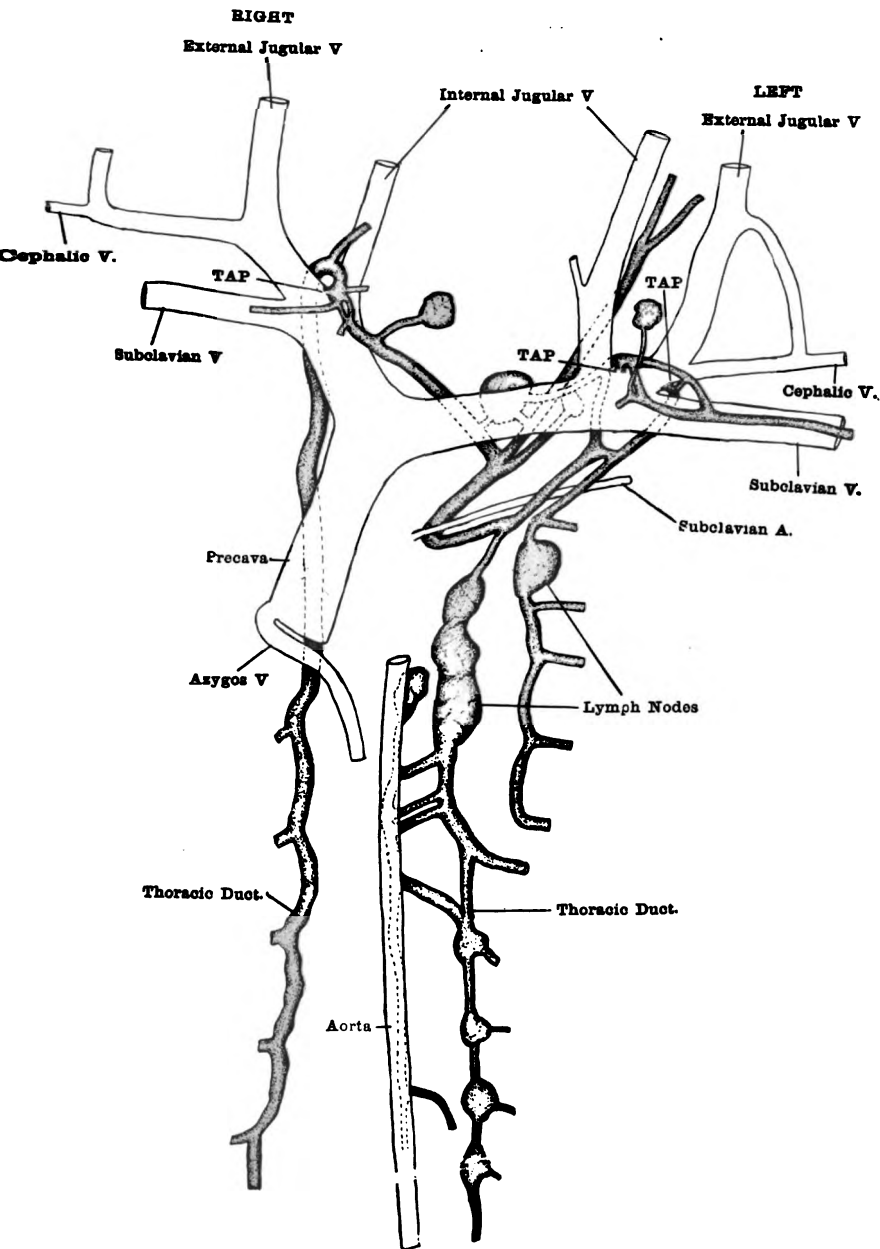


FIG. 5 (TYPE III)
Anubis Baboon ♂
Papio anubis, F. Cuv.

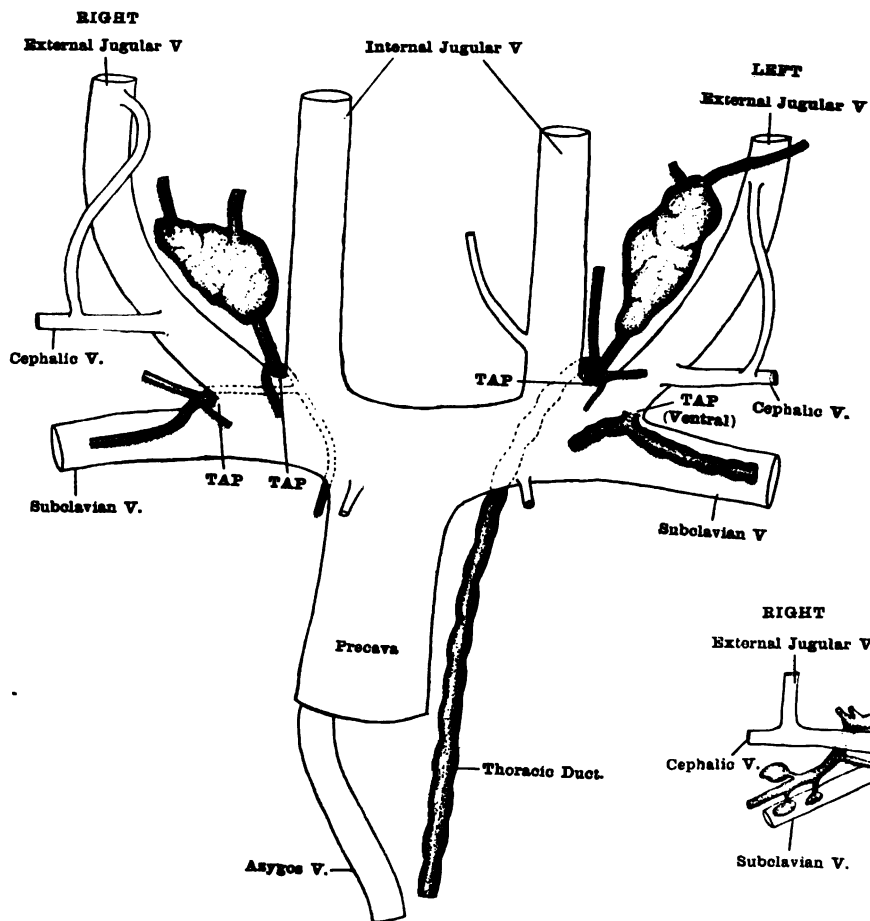


FIG. 6 (TYPE I)
 Chacama Baboon ♂
Papio porcarius, Bodd.

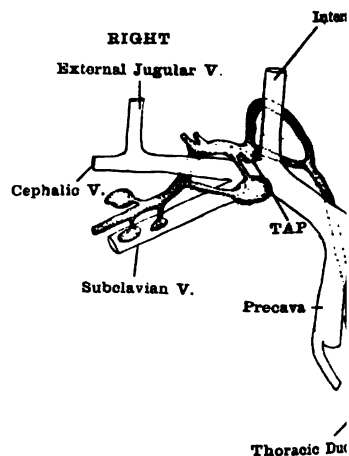


FIG. 7
 Japanese
Macacus ♂

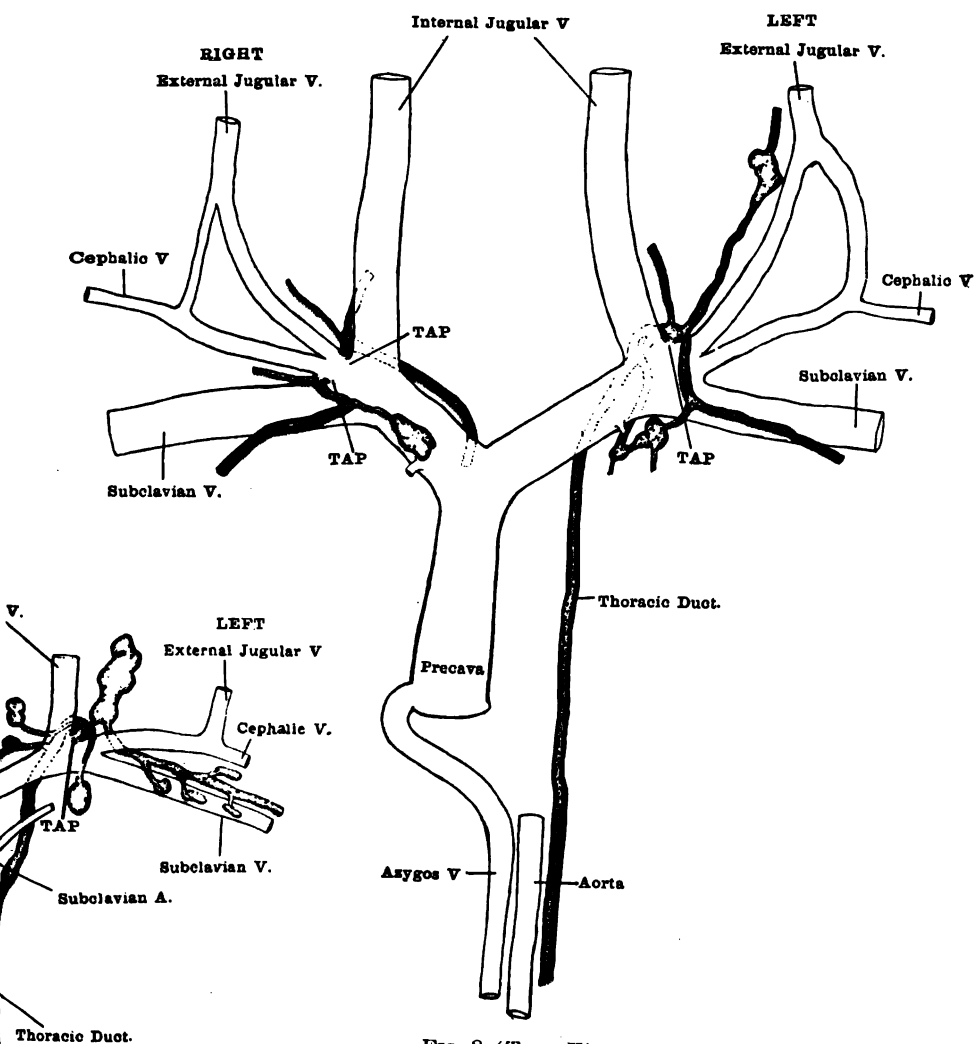


FIG. 8 (TYPE V)
Rhesus Monkey ♀
Macacus rhesus, Audebert

II)
e ♂
us, Cuv.

LYMPHATICO-VENOUS COMMUNICATIONS.

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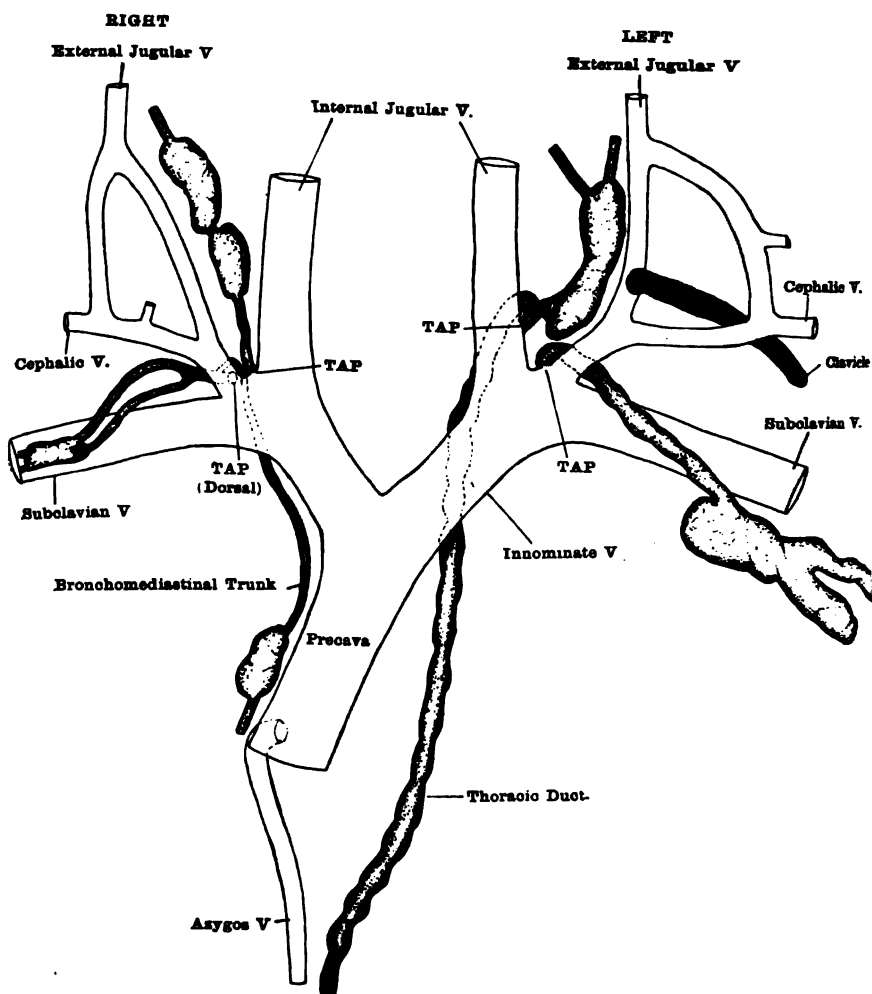


FIG. 9 (TYPE II)
Pig-tailed Macaque ♂
Macacus nemestrinus, Linn.

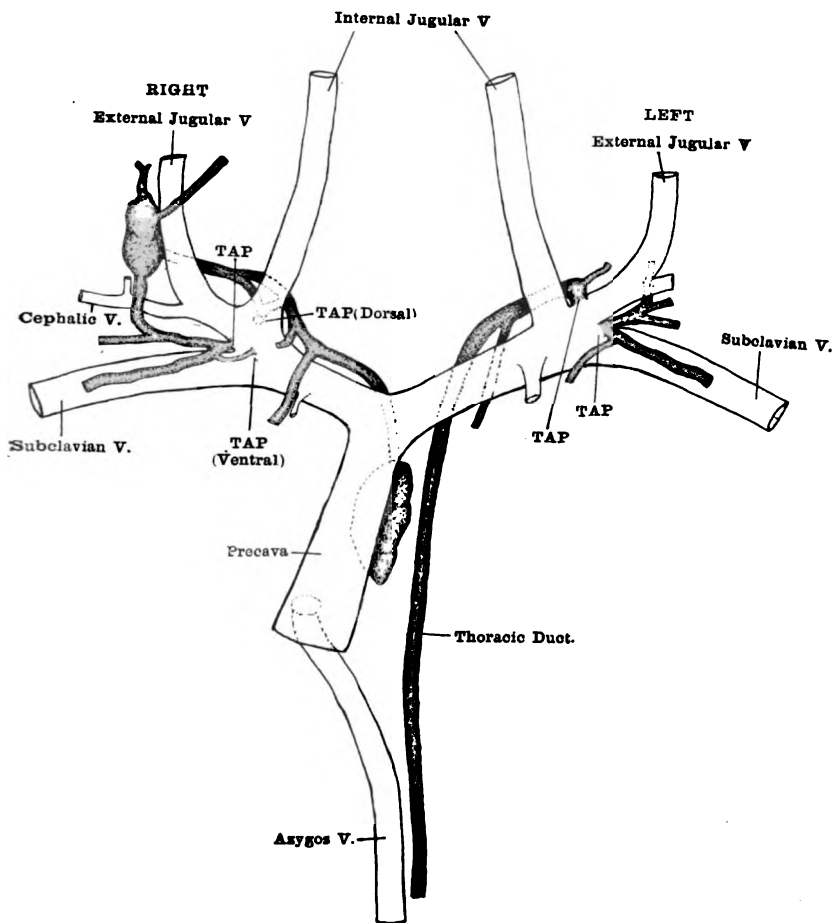
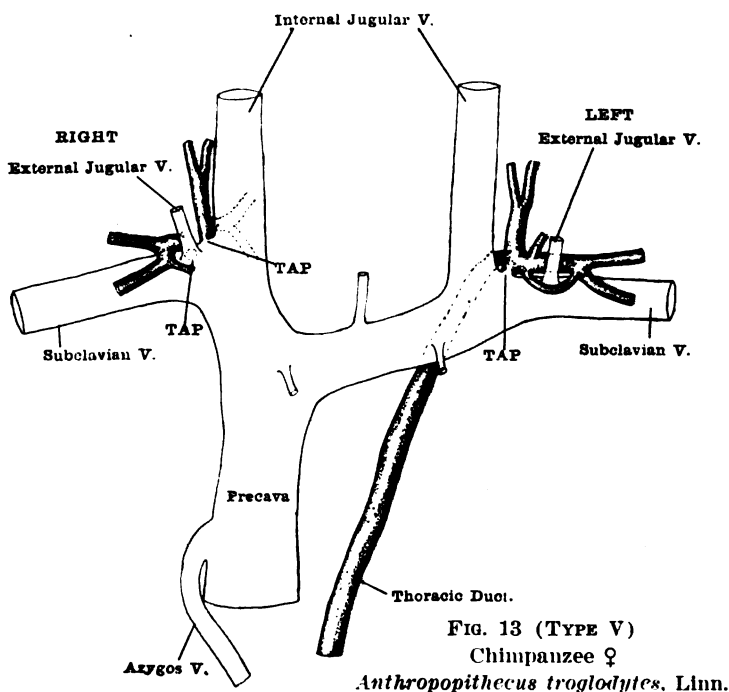
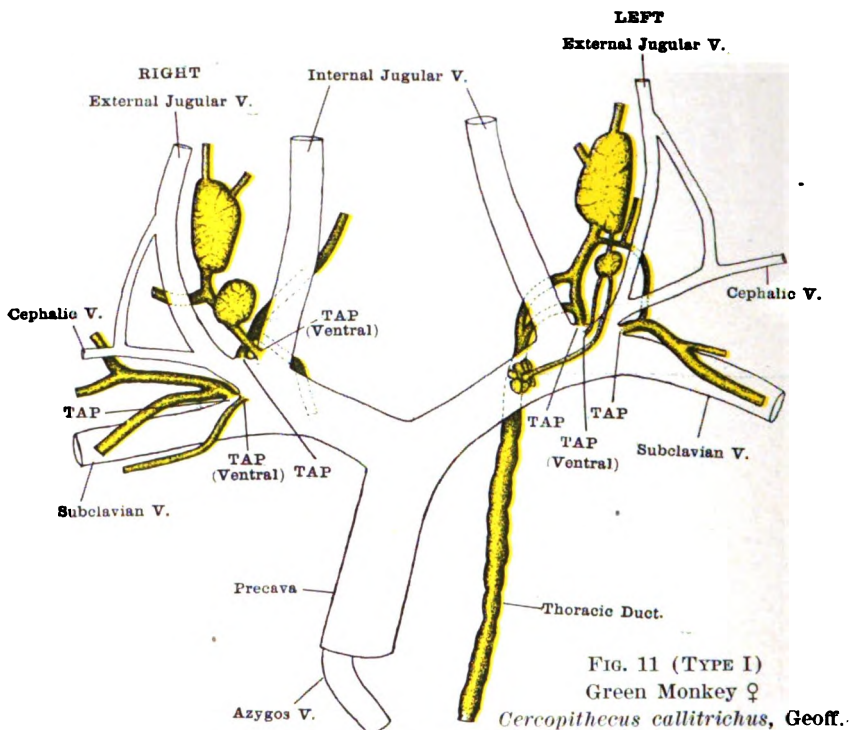
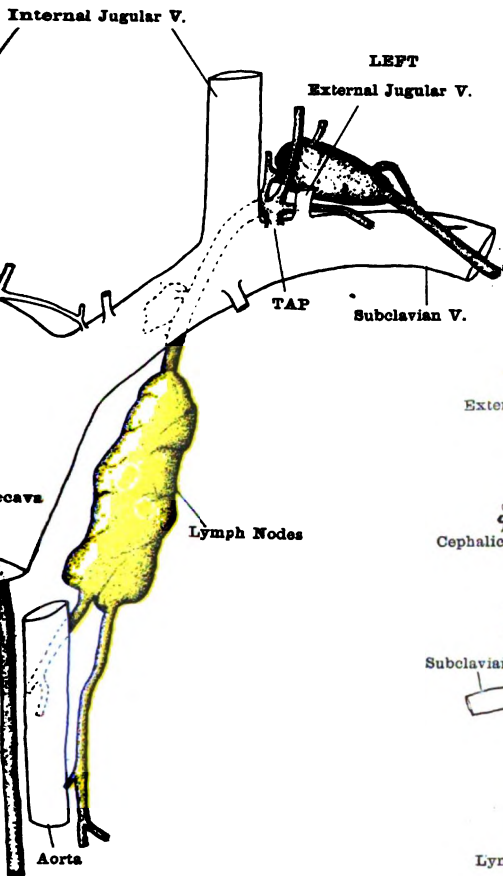


FIG. 10 (TYPE I)
Green Monkey ♂
Cercopithecus callitrichus, Geoff.

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(TYPE II)
chimpanzee ♂
Pan troglodytes, Linn.

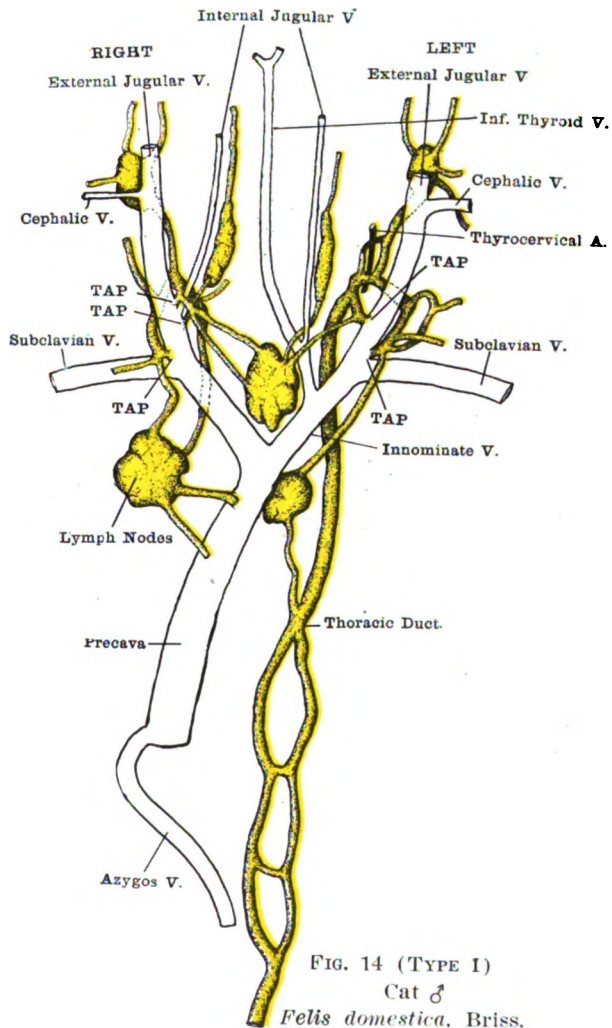


FIG. 14 (TYPE I)
Cat ♂
Felis domestica, Briss.

LYMPHATICO-VENOUS COMMUNICATIONS.

CHARLES F. W. MCCLURE AND CHARLES F. SILVESTER.

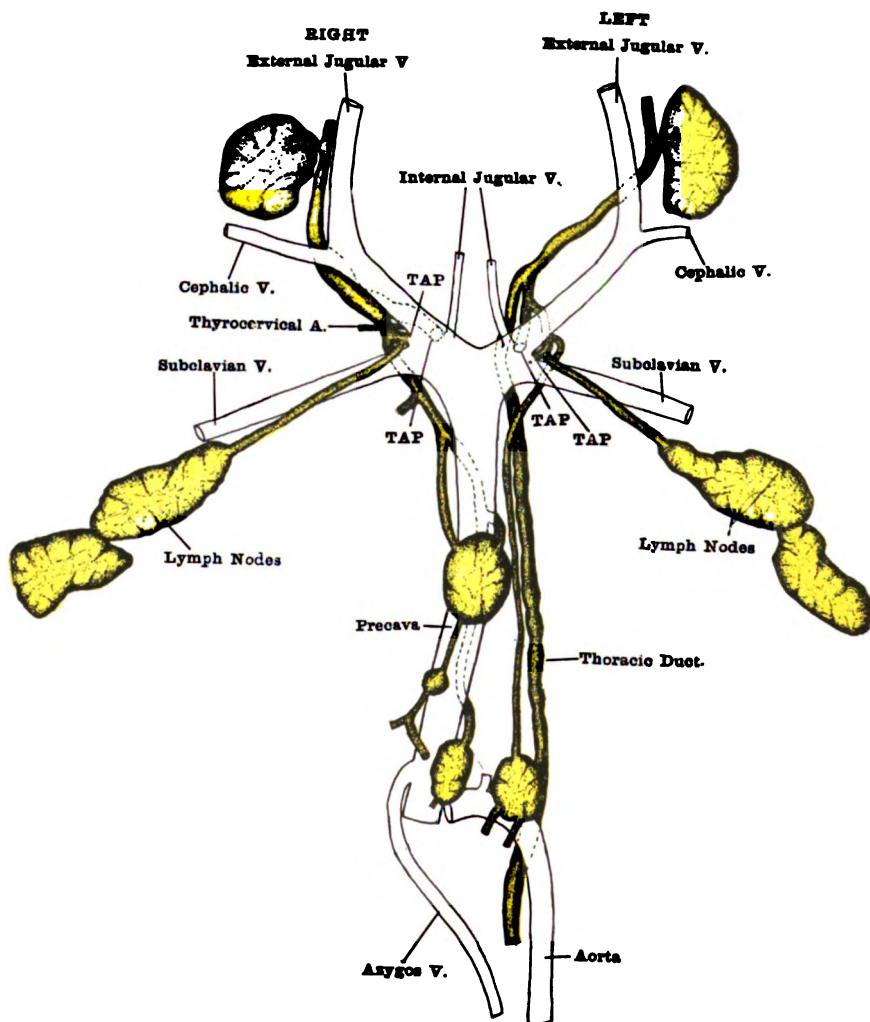
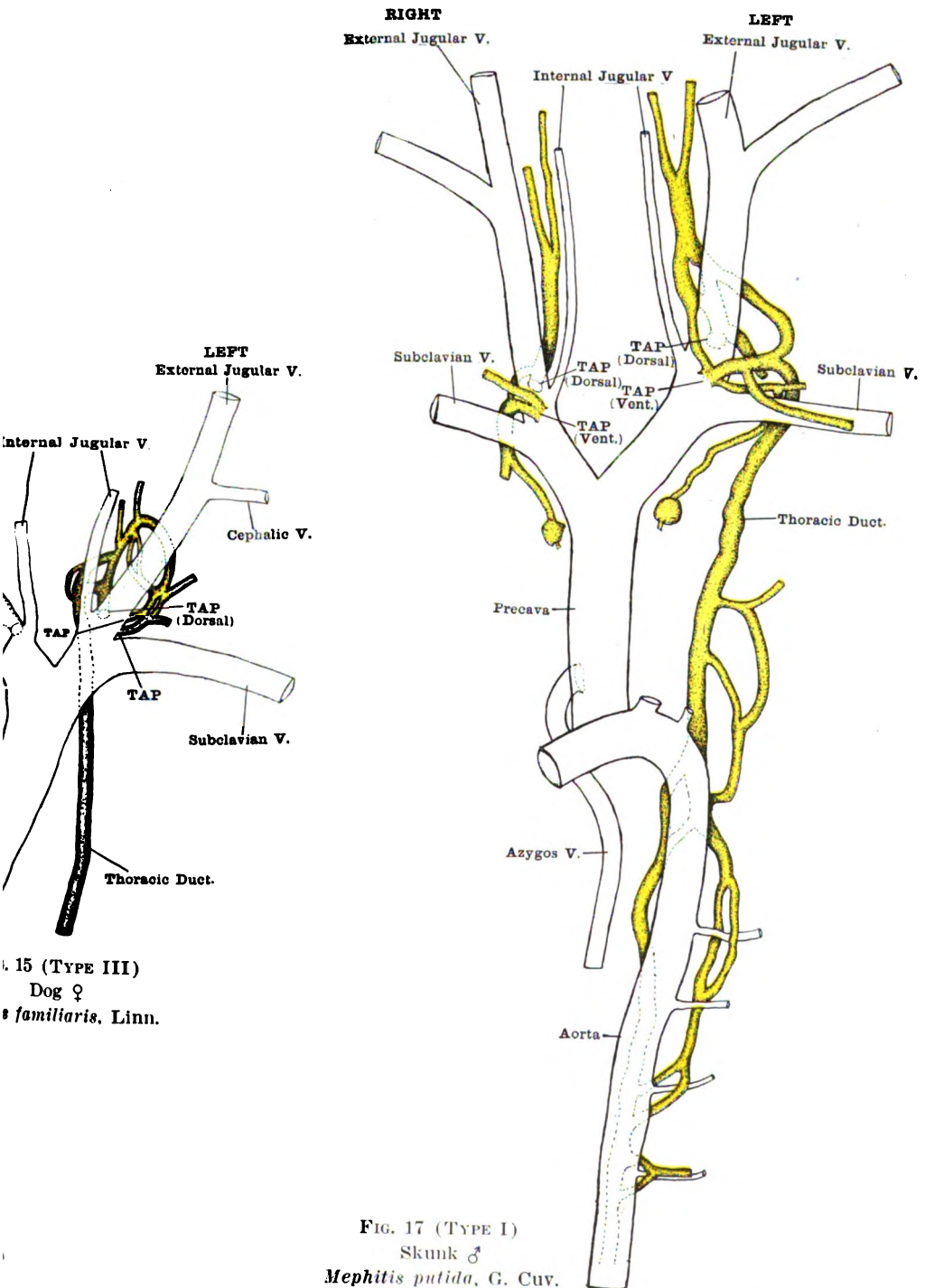


FIG. 16 (TYPE I)
Mink ♂
Putorius vison. Brisson



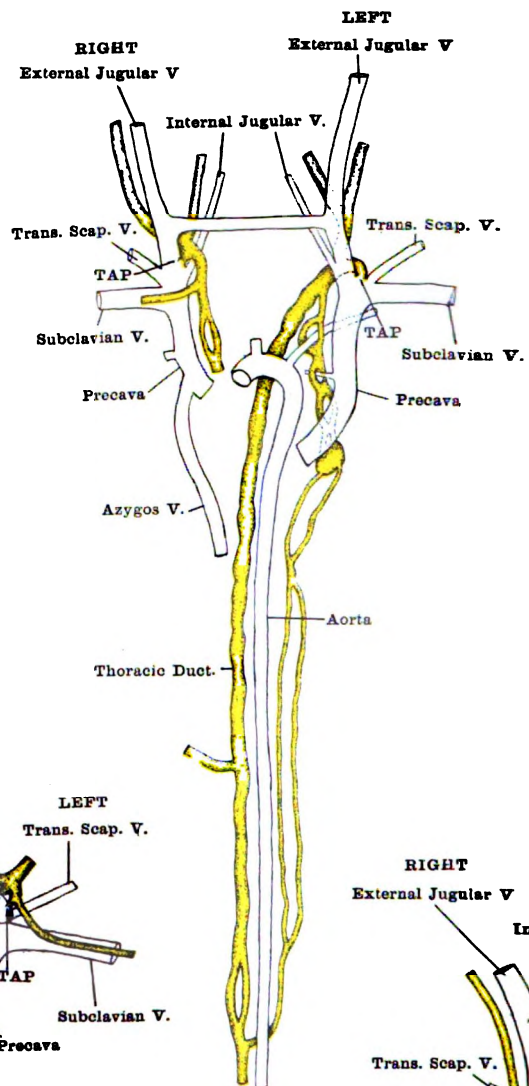


FIG. 19 (TYPE VI)
Rabbit ♂
Lepus cuniculus, Linn.

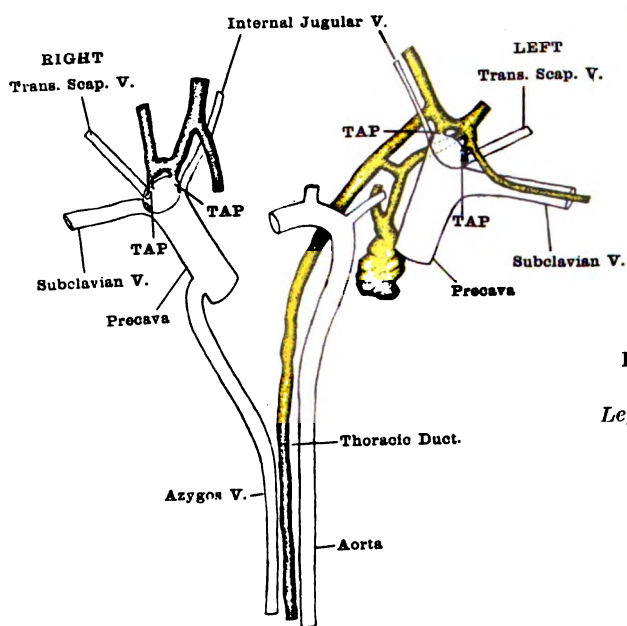


FIG. 18 (TYPE I)
Rabbit ♂
Lepus cuniculus, Linn.

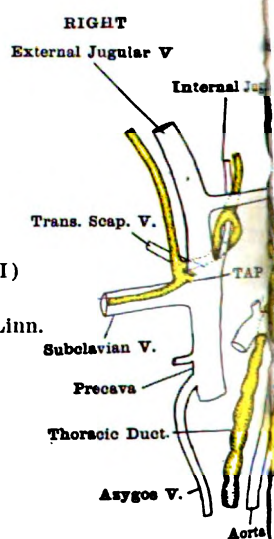


FIG. 20
Rabbit ♂
Lepus cuniculus, Linn.

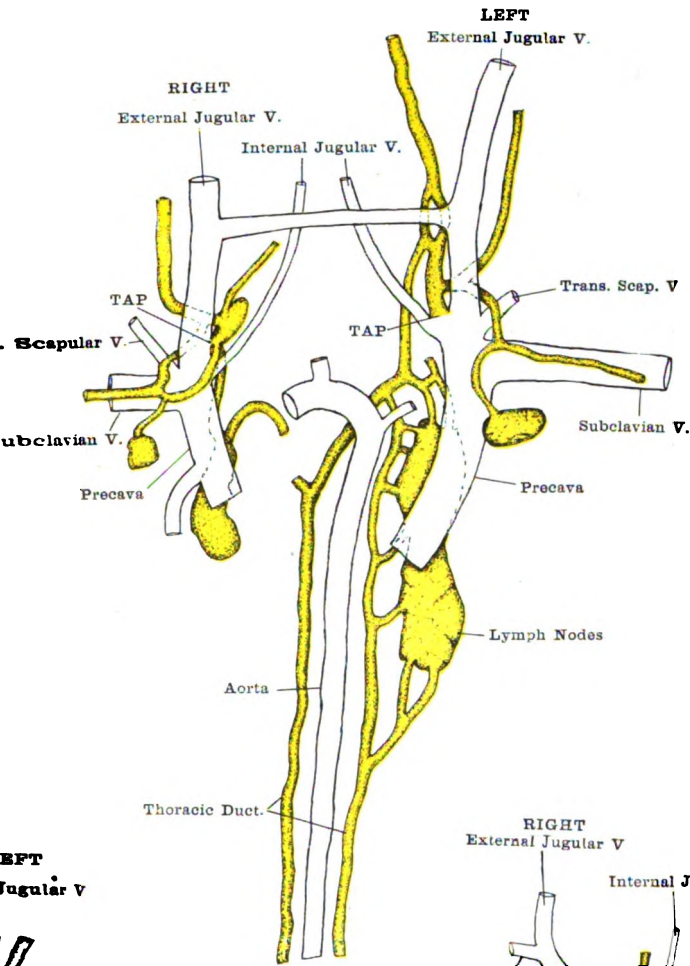


FIG. 21 (TYPE II)
Rabbit ♀
Lepus cuniculus, Linn.

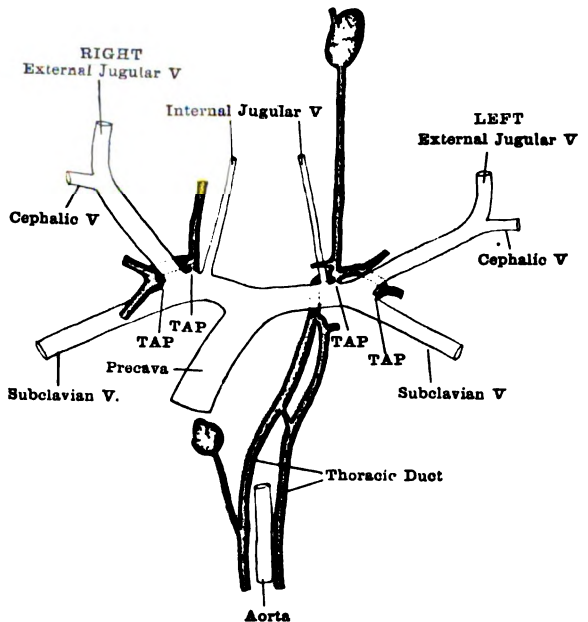
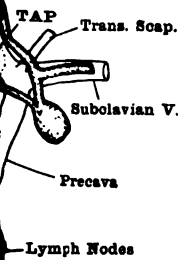


FIG. 22 (TYPE I)
Guinea-Pig ♂
Cavia porcellus, Linn.

LYMPHATICO-VENOUS COMMUNICATIONS.

CHARLES F. W. MCCLURE AND CHARLES F. SILVESTER.

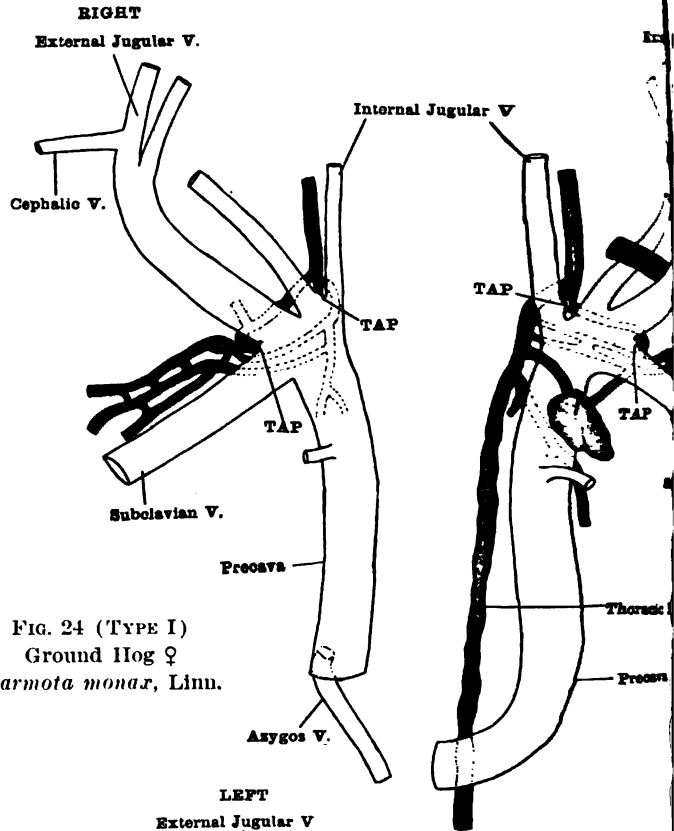


FIG. 24 (TYPE I)
Ground Hog ♀
Marmota monax, Linn.

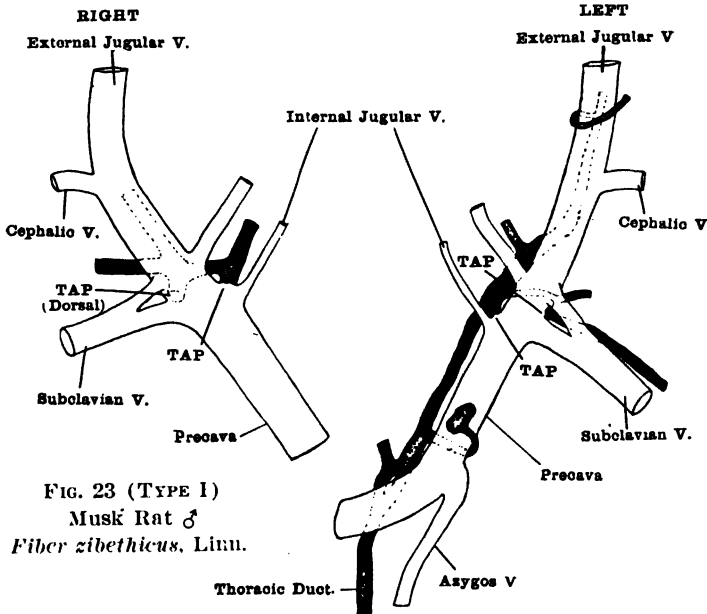


FIG. 23 (TYPE I)
Musk Rat ♂
Fiber zibethicus, Linn.

lio V.

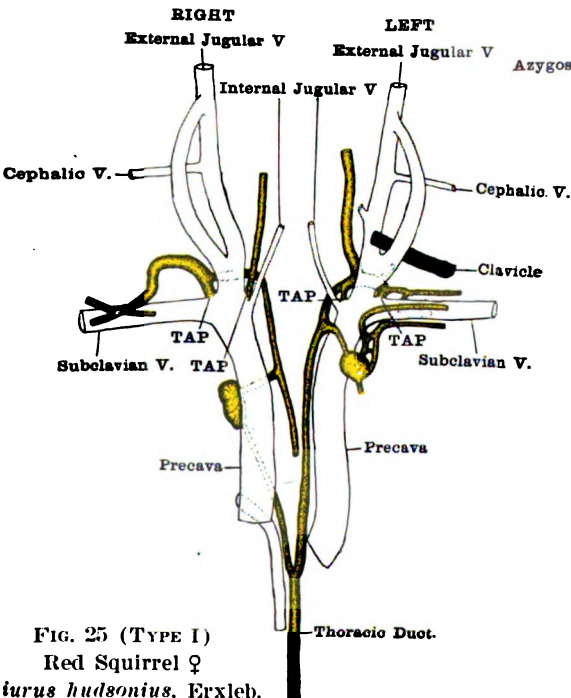
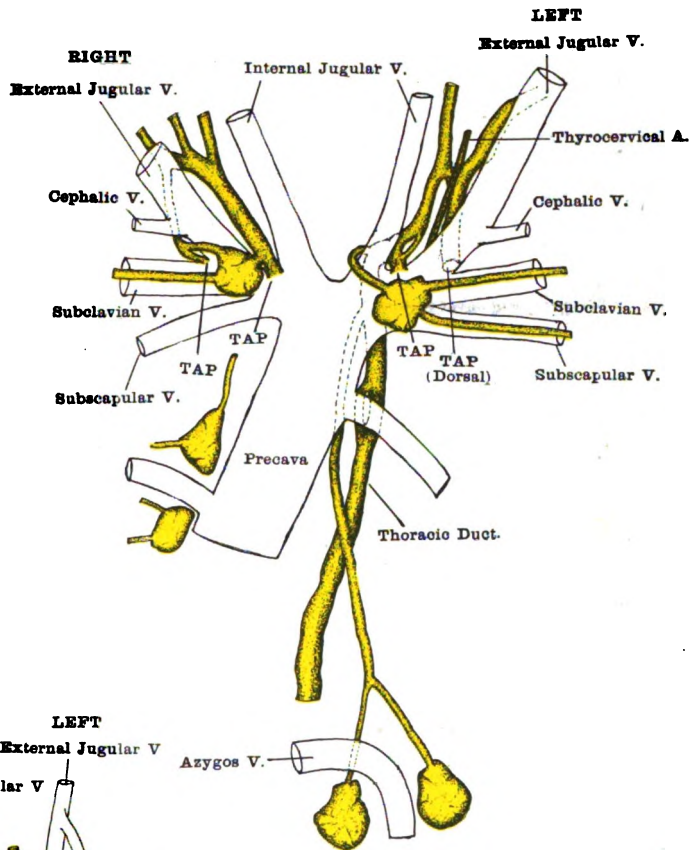


FIG. 26 (TYPE I)
Fig ♀
Sus scrofa domestica, Gray

LYMPHATICO-VENOUS COMMUNICATIONS.

CHARLES F. W. MCCLURE AND CHARLES F. SILVESTER.

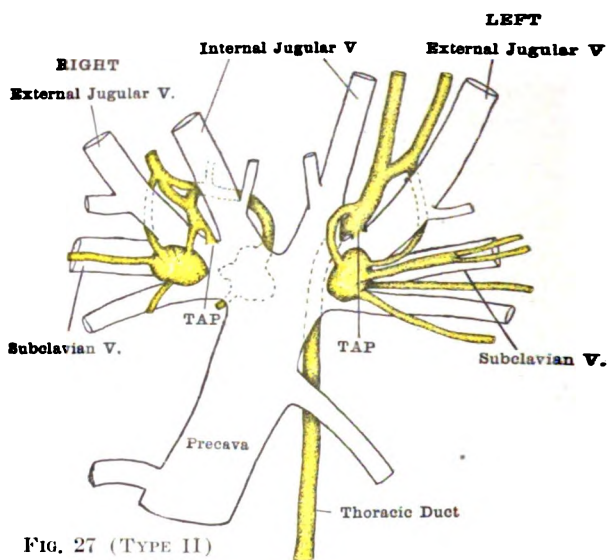


FIG. 27 (TYPE II)

Pig ♀

Sus scrofa domestica, Gray

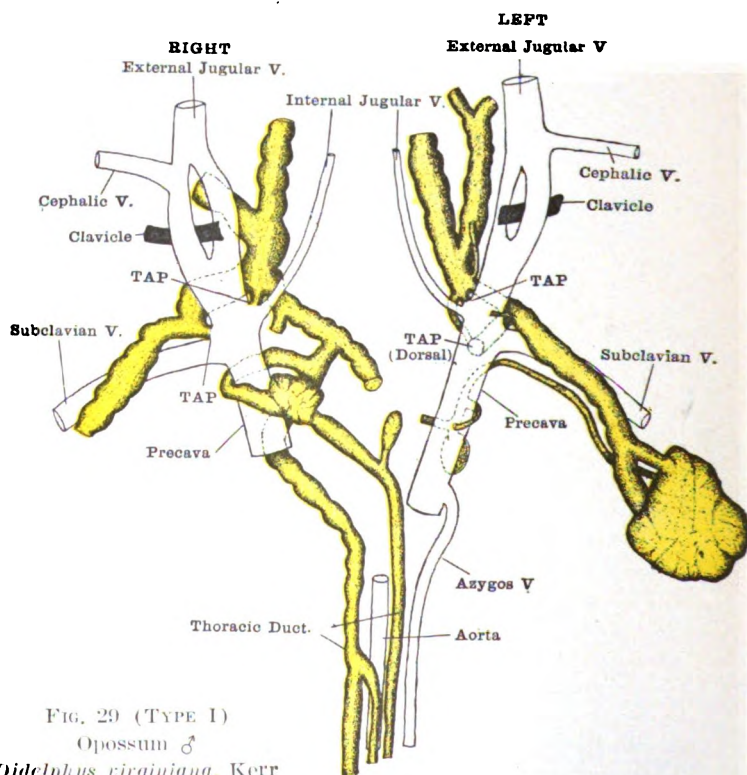


FIG. 29 (TYPE I)

Opossum ♂

Didelphys virginiana, Kerr

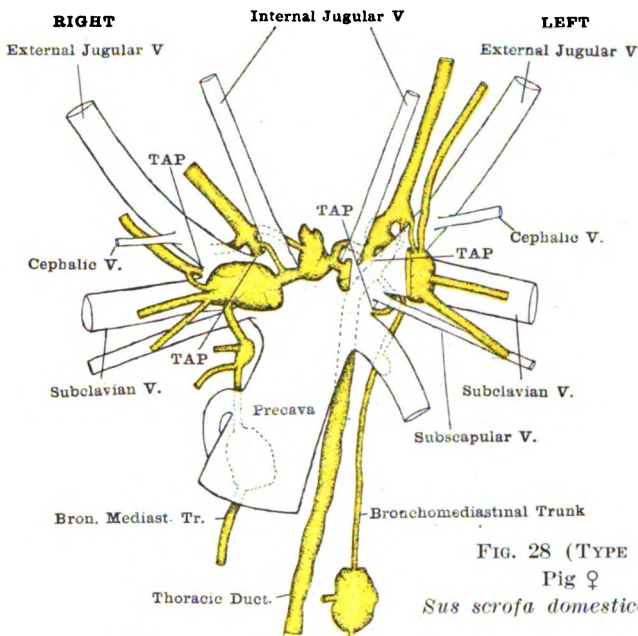


FIG. 28 (TYPE I)
Pig ♀
Sus scrofa domestica, Gray

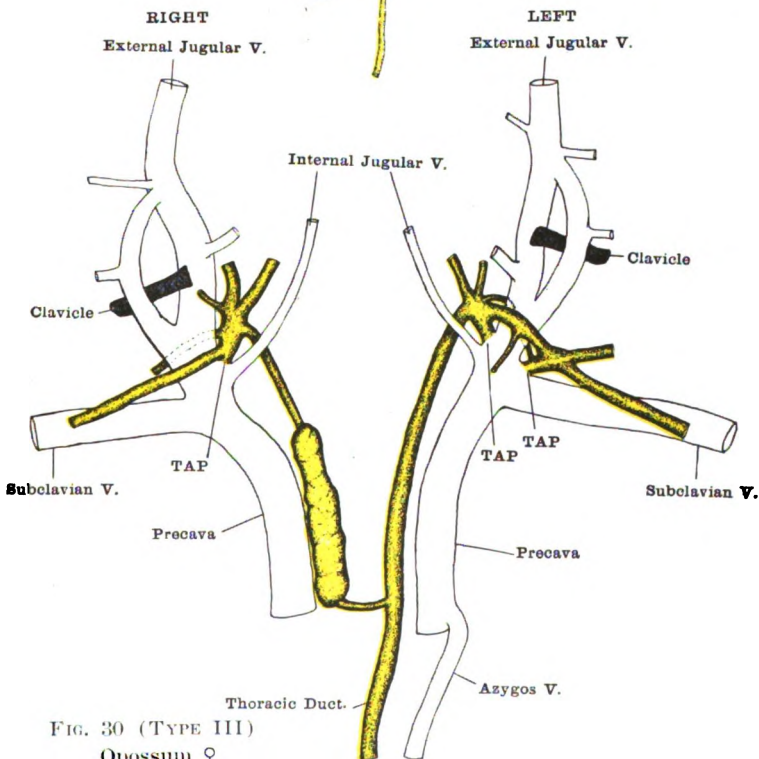


FIG. 30 (TYPE III)
Opossum ♀
Didelphys virginiana, Kerr

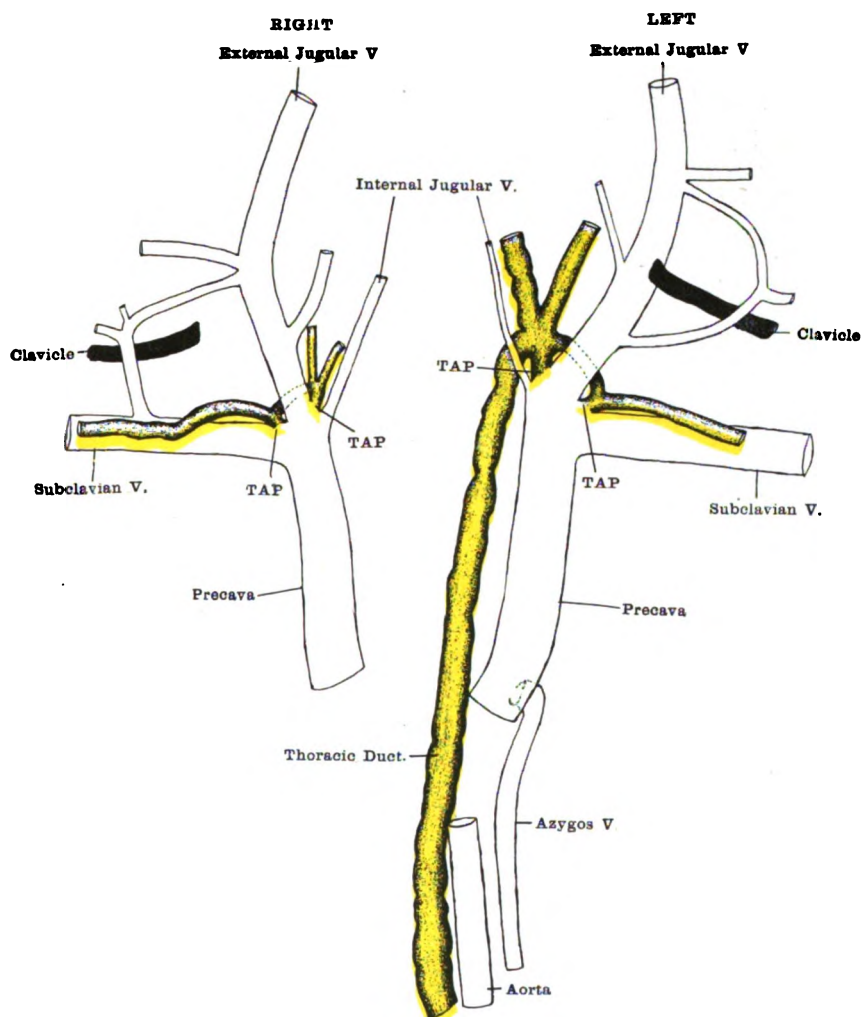


FIG. 31 (TYPE I)
Opossum ♂
Didelphys virginiana. Kerr

NOTES.

Doctor Irving Hardesty has been appointed Professor of Anatomy in Tulane University. The department, which formerly included only gross anatomy, will now have charge of histology as well. Professor Hardesty will be assisted by Assistant Professor Henry W. Stiles, M.D., formerly of the University of Michigan; Assistant Professor Henry Bayou, A.M., M.D., and Mr. H. H. Bullard, A.B., M.S., formerly of the University of Missouri, who will be Instructor in Anatomy. The following physicians will be assistant demonstrators: Dr. Sidney P. Delaup, B.Sc.; Dr. Marion S. Souchon; Dr. John F. Oechsner; while Dr. Charles A. Wallbillich, Dr. John F. Points and Dr. M. H. McGuire will be junior assistant demonstrators. Professor Hardesty, Professor Stiles and Mr. Bullard, as well as the technical assistant, Mr. Linstaedt, will give their entire time to the department. Dr. Edmond Souchon has been made Professor Emeritus of Anatomy and Curator of the Museum.

Richard E. Scammon, A.M. (University of Kansas), has recently been awarded the degree of Doctor of Philosophy by the Faculty of Arts and Sciences of Harvard University, for studies in medical sciences, particularly in embryology. He is thus the first candidate to avail himself of the new arrangement whereby this degree may be obtained by study and investigation conducted in the Medical School. Dr. Scammon's thesis will be published as the *Normentafel zur Entwicklungsgeschichte des Squalus acanthias* in Professor Keibel's series.

THE ANATOMICAL RECORD

Vol. III.

NOVEMBER, 1909

No. 11

A NOTE ON THE ORGANIZATION OF THE VENOUS RETURN WITH ESPECIAL REFERENCE TO THE ILIAC VEINS.

BY

H. VON W. SCHULTE AND FREDERICK TILNEY.

From the Anatomical Laboratory of Columbia University.

WITH ELEVEN FIGURES.

This paper is an attempt to formulate a few general propositions having reference to the organization of the venous system as a whole, and further to indicate some of the underlying hydrodynamic factors incident to the formation of the major lines of drainage. Broadly speaking, the veins of the mammal between the peripheral capillaries and the heart fall into two fairly definable regions, a central district of large venous trunks and a distal region of smaller plexiform vessels. The circulation in the adult differs from that of its embryo largely in the reduction of these plexuses to form larger single veins, the zone of plexiform veins retreating farther toward the periphery.

The result of the substitution of large trunks for plexuses is the reduction of the impediment offered to the venous return by surface friction, consequently either a reduction of cardiac work or, the work performed by the heart remaining the same, a more rapid circulation and potentially a higher rate of metabolism.

We conceive that it is the general competency of the circulation as a whole, rather than the topographical situation of the lines of

venous drainage, which is of evolutionary significance. *Natural* selection would easily be imagined to operate to destroy an animal whose venous system offered too great a resistance to the flow of the blood, while it is by no means obvious that, given a circulatory competency, the exact topography of a vein can often be of moment to its possessor. The high variability of veins is common knowledge and lends support to this view.

A cursory examination of the variations of the venous system in the three forms most extensively studied, man, the opossum¹ and the cat,² suffices to show that while variations in the situations of the individual veins and even in the topography of the major trunks are wide in range and frequent in occurrence, yet points at which plexus formations replace single veins are subject to relatively little change—the anatomic plan varies widely within limits rigidly fixed by physiologic efficiency. It might then fairly be expected that the evolution of the venous system, in its broad outlines, should be in the direction of organization and higher physiological efficiency, rather than the formation of a series of morphologic types. From this standpoint the venous system of the monotremes appears to us a generalized type of low organization, comparable to the embryonic veins of marsupials and placentals.

In *Ornithorhynchus* the plexiform arrangement involves even the postcavæ to the renal level (Figs. 1 and 2). The two vessels are connected dorsally by massive anastomoses. Traced caudad to about the lumbo-sacral junction each postcava resolves itself into two extensive plexuses, one dorsal and the other ventro-mesial to the *psoas minor*. At the lateral border of the muscle a wide channel connects the two plexuses; the dorsal plexus is composed of tributaries, enumerated cephalo-caudad as follows:

1. An ilio-lumbar plexus.

¹McClure, C. F. W., '03. "A Contribution to the Anatomy and Development of the Venous System of *Didelphys marsupialis*." Part I. *Amer. Jour. Anat.*, Vol. II, No. 3.

²Darrach, W., '07. "Variations in the Postcava and its tributaries as observed in 605 Examples of the Domestic Cat." *Amer. Jour. Anat.*, Vol. VI, No. 3, page 30.

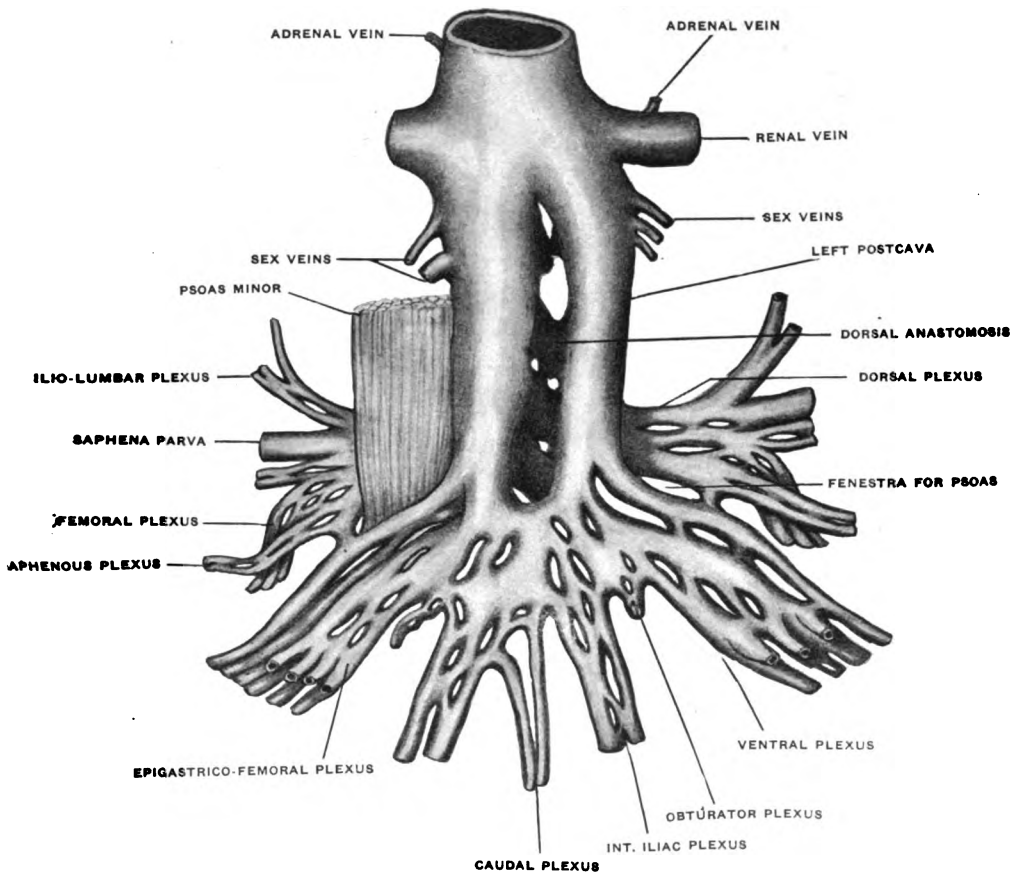


FIG. 1. *Ornithorhynchus paradoxus*. From a dissection in the study collection of the Department of Anatomy, Columbia University. Showing the postcavæ and their tributaries. Ventral view, semi-diagrammatic. The aorta and branches have been omitted to allow the dorsal anastomoses between the postcavæ to come into view. The psoas minor of the left side is also omitted.

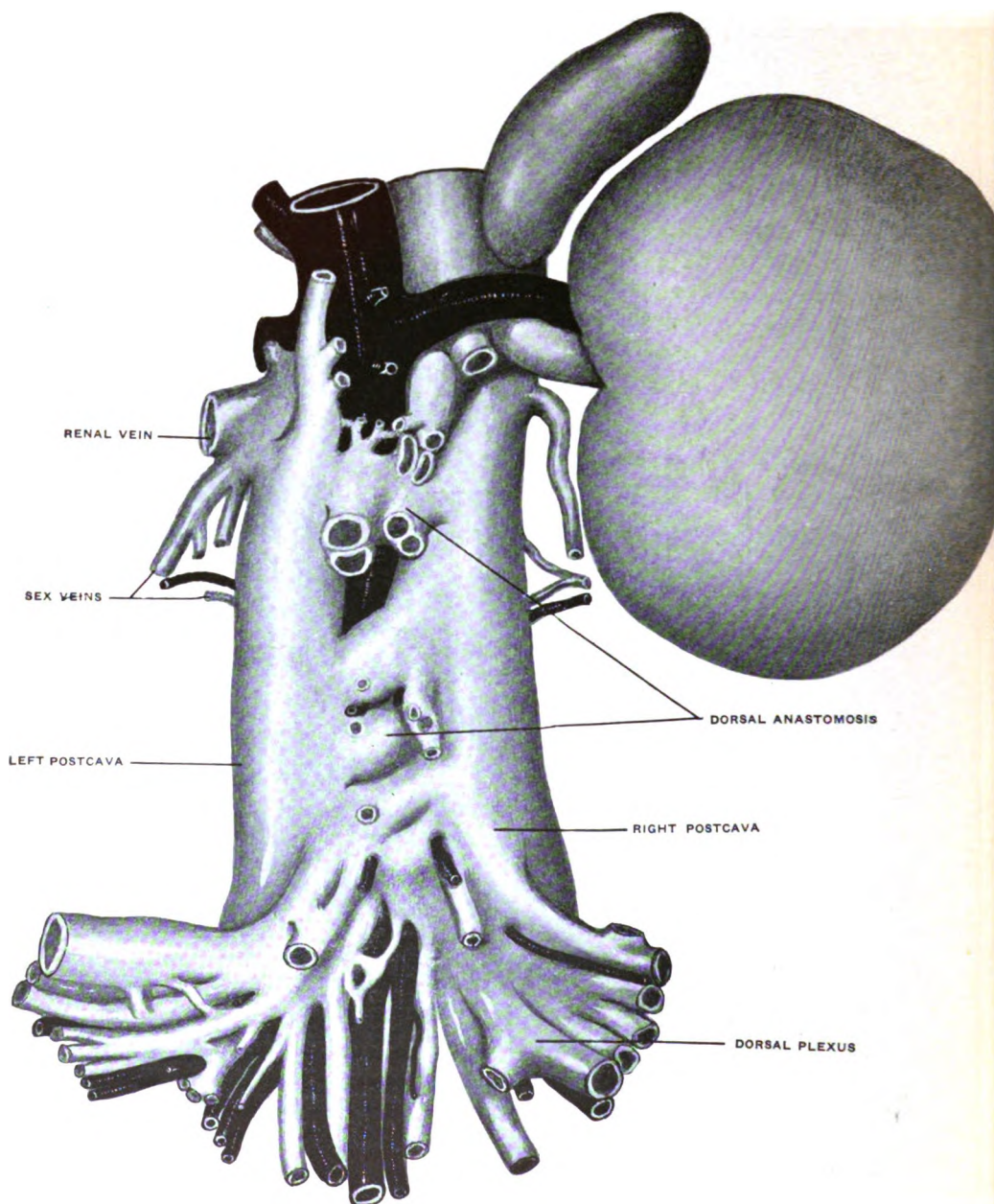


FIG. 2. *Ornithorhynchus paradoxus*. Dorsal view. From a dissection in the study collection of the Department of Anatomy, Columbia University. After injection the vessels were removed in mass.

2. A large trunk from the dorsum of the thigh (*saphena parva*).
3. Veins coming from the fat pad of the groin.
4. A femoral plexus.

It is noteworthy that the drainage from the panniculus and the sub-pannicular fat of the trunk is accomplished by large veins (*vide supra* 2 and 3), while that from the deeper parts is given by the plexiform vessels accompanying the arteries. The ventro-mesial plexus is composed from without inward of the following plexiform vessels:

1. A deep epigastric which receives a considerable plexus from the thigh.
2. An internal iliac, receiving the obturator and vesico-pudendal plexuses.
3. A caudal plexus.

Across the median line the plexuses of the two sides anastomose freely dorsad of the aorta, and ventrally more or less completely across its large branches.

It is, of course, arguable that the circulatory system of *Ornithorhynchus* is not primitive, but highly specialized in adaptation to the animal's semi-aquatic habits. Resembling, as it does, the venous plexuses of the cetacea, though it differs in degree and constitution, no one would deny that it stands in relation to the creature's habits. But it by no means follows that it is highly specialized, since a retention of the embryonic characters in the adult may have as high adaptive value as the development of new characters. In the extensive plexus formation, the thin walls of the vessels and the excess in lumen of the veins over the arteries, we have a picture closely resembling the vessels of the embryos of higher forms,—a system of vessels in which a relatively small column of blood reaches the capillaries through the small and often plexiform arteries, accumulates in the veins and sluggishly returns to the heart. This condition is undoubtedly one of low physiological organization, fitted by the multiplicity of its venous paths to serve as a composite schema of the variants of the venous system in higher mammals. Further in *Echidna*, which is not an aquatic animal, but little reduction of the plexus has

occurred. It is significant that this reduction affects the **postaortic anastomoses**.

In turning from the monotreme to the marsupial, we find in the latter an immense advance in the organization of the venous return. Not only the postcava but also the iliac and often the caudal vein are free of plexus formation, though there is not infrequently a remnant of the plexus in the form of "venous islands" in the region of the promontory, yet even these are fewer than in such placental forms as the edentate or even the cat, and they are far less extensive than in cetacea.

If the plexuses of monotremes are primitive, as we take them to be, it becomes a problem to deduce from them the trunk drainage of the marsupials and placentals. A few details of the morphology of the marsupial veins are a necessary preliminary.

In a specimen of *Trichosurus* (Fig. 3) the cava is formed by the confluence of a number of radially disposed vessels, the ilio-lumbar, external iliac and internal iliac veins. The left internal iliac receives the caudal. The specimen shows, perhaps, a slight tendency to the formation of a common internal iliac trunk. Compared to this the monotreme presents a great excess of vessels in its fan-shaped plexuses, while here we have, as it were, only the ribs of the fan, the intervening web reduced to small tributaries of the major trunks. Radial hydrodynamic lines have developed and there has followed, as must follow, a reduction of the network. It is obvious that if two converging veins of equal size are connected by a homogeneous reticulum, the blood flows from all parts of the reticulum under the *vis-a-tergo* of the arteries and the suction through the veins of the cardiac diastole (Fig. 4). It follows that the blood will flow from the center of the reticulum toward the large veins, and that the periphery will have not only to transmit the blood directly reaching its meshes but also to drain the central areas. Its function, therefore, is at a maximum near the large veins, and diminished toward the center where, as it were, a watershed is formed, dividing the reticulum into two drainage areas. The peripheral parts of the plexus persist as small tributaries of the veins favored by the hydrodynamic lines (Fig. 5), and resolve themselves into smaller vessels and capillaries

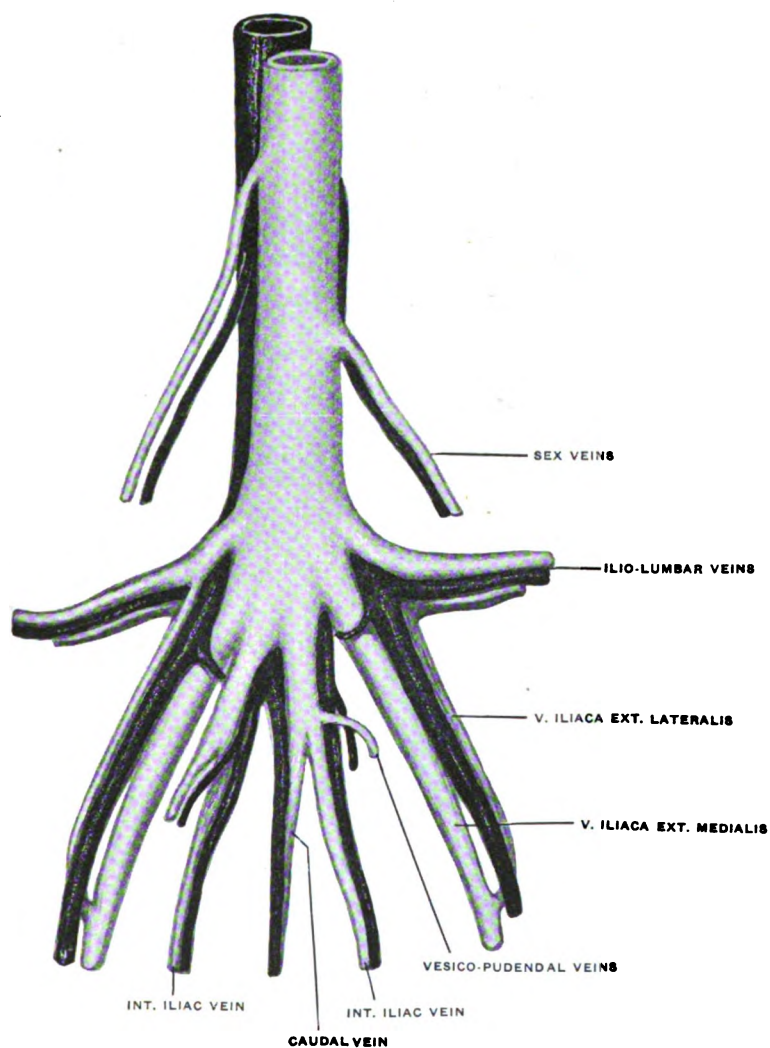


FIG. 3. *Trichosurus vulpecula*. From a dissection in the study collection of the Department of Anatomy, Columbia University. Postcava and pelvic veins showing radial arrangement.

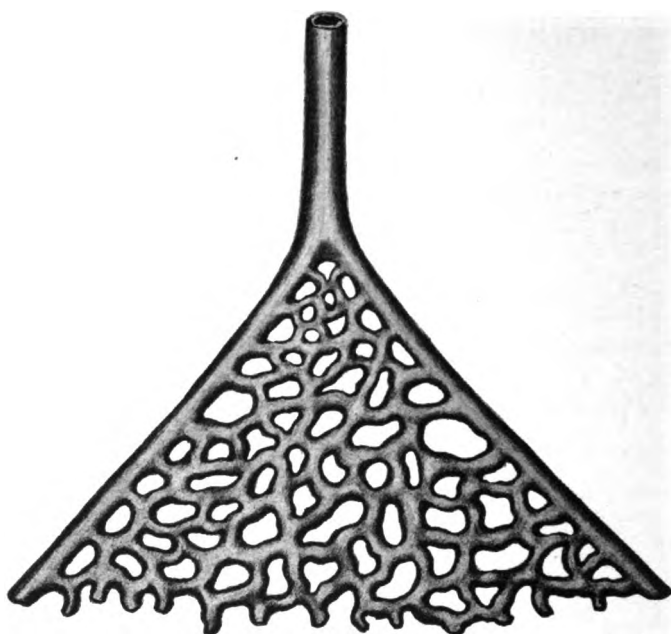


FIG. 4.

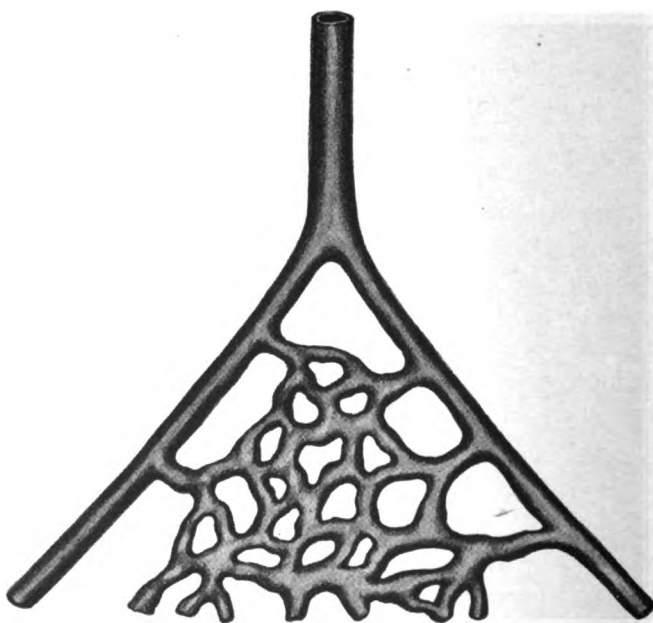


FIG. 5.

as the divide is approached. Our knowledge of the ontogeny of the pelvic vessels in marsupials is unfortunately small, yet it seems fair to argue from the redundancy of foetal vessels everywhere, that some such reducing factor as we have mentioned is active mechanically in occasioning the substitution of trunk vessels for plexus formation.

The radial arrangement of the pelvic vessels described above appears to be unstable even in *Trichosurus*. (Fig. 6.) Besides the specimen of *Trichosurus* figured, it occurs, so far as we are aware, only in *Pseudochirus* where it is complicated by the presence of venous rings about the large arteries. Elsewhere the arrangement is disturbed by a tendency of adjacent, ultimately confluent trunks to form a common vessel of greater or less extent, transforming the V shape of their union into a Y, and giving rise to an apparent distad recession of the angle of union. The trunks thus affected are the external and internal iliacs with the resultant common iliac—an almost constant formation in the Australian marsupial—or the two internal iliacs to produce a common internal iliac as often in *Didelphys virginiana*. *Trichosurus* appears as the starting point of these two types, inclining, however, markedly to form a common iliac. In either case the result is the same, the reduction of friction and a displacement of the angle of confluence distad. This phenomenon seems capable of mechanical explanation. Given two equal veins inosculating proximally and connected distally with drainage areas which are increasing in size, an increasing venous return demands an increase in the size of the veins. The trunk proximal of the union tends to lie in the prolongation of the axis of the angle of union (Roux). At this point, therefore, the blood stream changes its direction. Its momentum may be decomposed by the parallelogram of forces into a moment acting in the axis of the resulting vessel and a moment at right angles to this, tending to push the walls of the tributaries into closer approximation and to form a spur at the angle of confluence (Fig. 8). Thus more and more the uniting vessels would tend to have their proximal segments parallel, with their walls in apposition. This spur will sustain the pressure of the blood stream upon both sides, which constitutes an abnormal

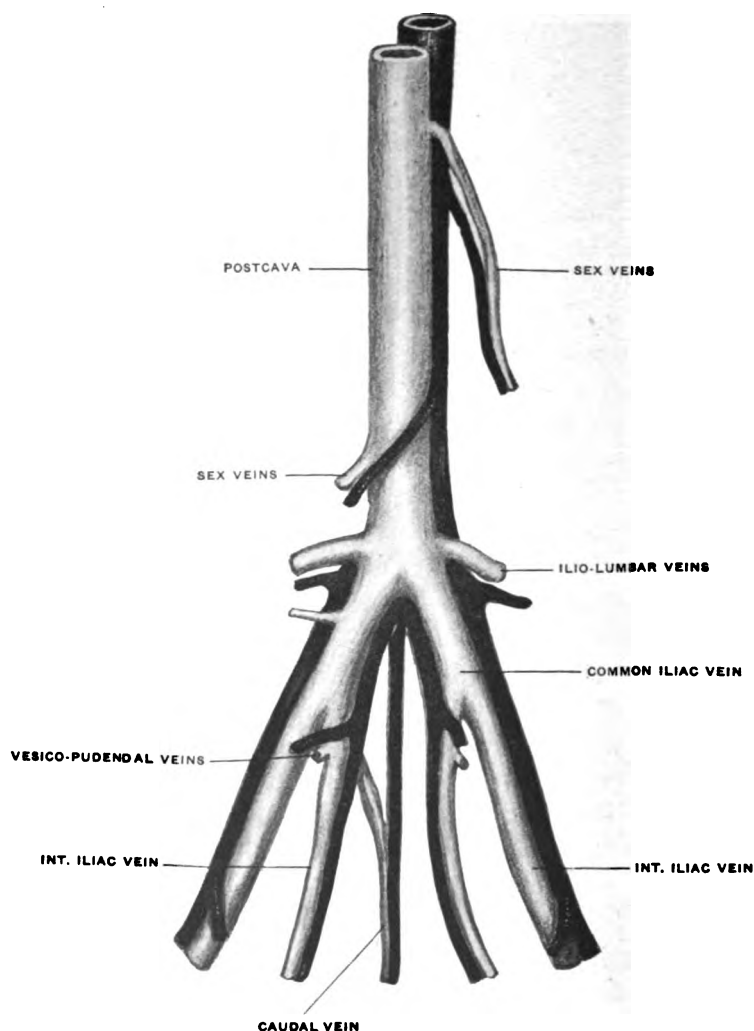


FIG. 6. *Trichosurus vulpecula*. From a dissection in the study collection of the Department of Anatomy, Columbia University. Showing common iliac type.

environment for its cells, tending to its ultimate reduction. McMurrich³ has reported cases in man of partial persistence of such formations in the iliac veins. Against this mode of accounting for the Y type, an alternative explanation may be argued. It might be held that the recession of the angle was apparent only, that actually a new confluence had been formed by the development of a cross

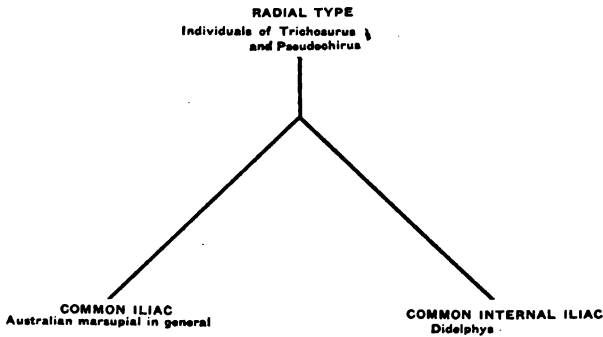


FIG. 7.

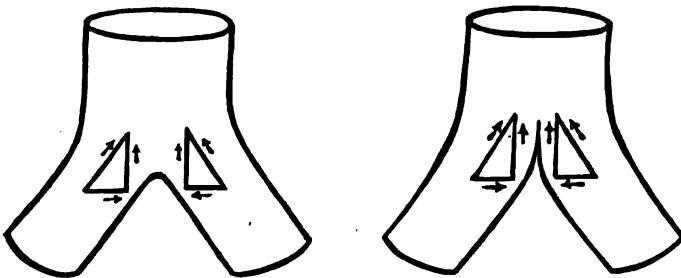


FIG. 8.

channel through a more distal portion of the reticulum. As will appear subsequently, we are far from denying this possibility, but interpret it as the disturbing result of factors extrinsic to the circulatory system itself, in fact as an example of the establishment of a

³McMurrich, J. P., '06. "The Occurrence of Congenital Adhesions in the Common Iliac Veins and their Relation to Thrombosis of the Femoral and Iliac Veins." Brit. Med. Jour., II, page 1890.

collateral circulation following interference in a hydrodynamic line (Fig. 9).

In our figure, should such a factor operate upon the segment B tending to its destruction, flow would be reversed in the reticulum previously draining into it, and a new channel such as C would result from the enlargement of portions of the reticulum responding to the

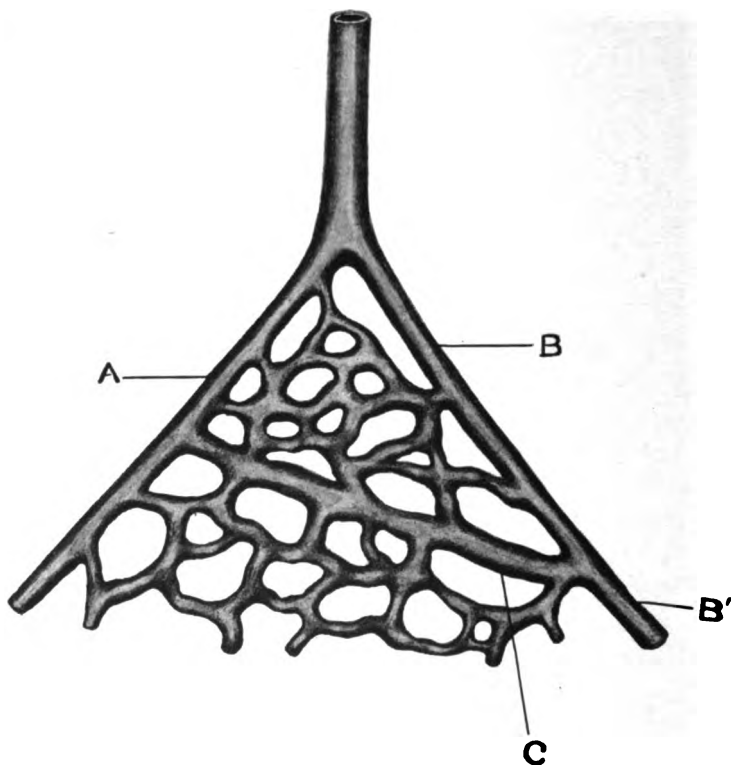


FIG. 9.

increased function required below the obstacle. But apart from such external interference, the line B would tend to be retained, for the inlet from B' is freer into B which is in line with it, than into the diverging channel C. A good illustration of the displacement of the angle distad is afforded by the vessels in the blastoderm of the chick.

The caudal vein in marsupials is subject to a wider range of varia-

tion than the iliac vessels. In *Phascolomys* (Fig. 10) in addition to a mouth in the left common iliac it is connected by three pairs of transverse branches with the internal iliacs, forming a sort of grill pattern. In one individual of *Phascolarctos* a closely similar arrangement was found. In both of these forms the tail is rudimentary. In other marsupials it usually opens by a single mouth into one or other common or internal iliac, only occasionally retaining the remnant of a plexus in multiple points of debouchment. Followed distad it soon breaks up (usually at the root of the tail) into a plexus surrounding the caudal artery. A distinction can thus be drawn between the large-tailed forms and those having short tails, in reference to the caudal vein, which in the latter forms retains more of its plexiform character. Evidently the size of the drainage area, the volume of blood to be transmitted, is the determining factor in the evolution of trunk veins as against plexuses. The existence of traces of plexus formation in some individuals of the *Macropodidæ* does not militate against this view, as here a large part of the caudal return is provided by subcutaneous channels.

In general the larger the area drained—the greater the length of the trunk in the proximal portion of its drainage line—the farther distal is the point at which the plexuses occur. A familiar example is the comparison of the *V. femoralis* and the *V. poplitea* in man with his *Vv. brachiales* which are plexiform. The caudal vein is, however, a more convincing example, as here such disturbing factors as might result from the upright position of man may be excluded.

The arrangements of the common and external iliac veins among the marsupials are of considerable theoretic importance. Two types may be distinguished in the relation of the vein and artery. In *Didelphys*⁴ the external iliac vein lies lateral to the artery. In the Australian marsupial the leg is drained by channels lying mesial to the artery (Figs. 3 and 10), external iliac and common iliac veins. Intermediate forms, however, occur. In *Trichosurus* and *Phascolomys*, for example, there is sometimes in addition to the large

⁴McClure, C. F. W., '03. "A Contribution to the Anatomy and Development of the Venous System of *Didelphys marsupialis*." Part I, *Amer. Jour. Anat.*, Vol. II, No. 3. (See plates.)

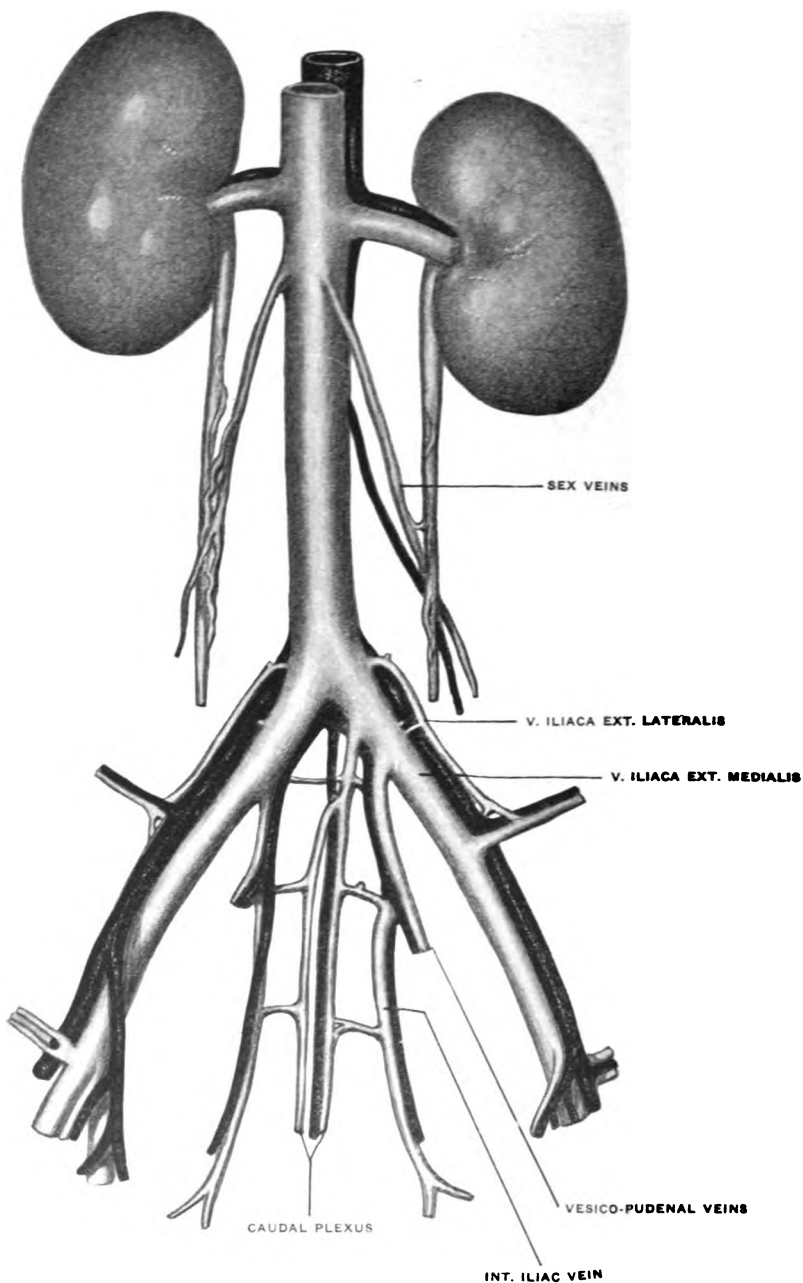


FIG. 10. *Phascolomys Mitchellii*. From a dissection in the study collection of the Department of Anatomy, Columbia University Showing vena iliaca externa lateralis, vena iliaca externa medialis and grill pattern of caudal veins.

mentally placed vessel a smaller lateral one, varying in development and inosculating distally with the external iliac near the groin, but not at a constant level. It receives tributaries from the psoas-iliacus and may show a plexiform character. In the elephant (Darrach) double external iliacs accompany the artery, one lateral, one mesial. The same arrangement occurs in the 20 mm. cat embryo (Huntington). In monotremes a plexus accompanies the arteries. The evidence, while admitted fragmentary, appears to us to warrant the conclusion that the external iliac vein results from the solution of a plexus.

While in the case of the internal iliac vein, reduplication of the vessel has not been observed among the marsupials, so far as we are aware, yet the variety in its relation to the artery—it may be dorsal or ventral, lateral or mesial—suggests a similar origin. And again the monotreme has the plexus.

The corollary follows that these homonymous great veins are not morphological equivalents; the *V. iliaca externa lateralis* is not morphologically the same as the *V. iliaca externa medialis*, but results from a specialization of a different area of plexus. The veins are homodynamous, agreeing in function, that is in the drainage of similar areas; and it thus appears that the anatomical names of veins designate not morphological but physiological units. The hydrodynamic line of drainage is far more constant than the morphological structures which compose it, and unconsciously this drainage line has been the subject of our nomenclature. A more striking illustration is afforded by the term *postcava*, as already pointed out by Dwight⁵ and Lewis.⁶ This vessel is composed of morphological, distinctly defined elements, *sinus venosus*, *vena hepatica communis*, hepatic sinusoids, subcardinal, supracardinal and postcardinal veins. In the marsupial the cardinal collateral⁷ replaces the supracardinal

⁵Dwight, Thomas, '01. "What constitutes the Inferior Cava." *Anat. Anzeig.*, Vol. XIX, pages 29-30.

⁶Lewis, F. T., '02. "The Development of the Vena Cava Inferior." *Amer. Jour. Anat.*, Vol. I, No. 3.

⁷McClure, C. F. W., '06. "A Contribution to the Anatomy and Development of the Venous System of *Didelphys marsupialis*." Part II, Vol. V, No. 2. (See page 194.)

in this list. The post-renal element may be cardinal, supracardinal or cardinal collateral; it may be double or single to the right or left in front of the aorta. Apart from its parallelism to the aorta, its only constant character is that it drains the tail, the hinder extremity and one or both of the gonads according to its site, at one side or in front of the aorta. It is obvious that we are dealing with a definite line and area of drainage, which may be affected indifferently well by any one of a series of vessels. The term postcava only indicates this hydrodynamic line. The case here is essentially the same as we have attempted to show for the external iliac. A venous plexus surrounding the aorta is antecedent to the formation of trunk vessels. The variously named cardinals are merely dilated portions of this reticulum along the major hydrodynamic lines, which, responding to the large volume of blood they transmit, dominate the picture. The smaller transverse channels were long treated as of little morphological importance, except where from external factors in the course of development, the flow became retarded in one of the longitudinal vessels, when they entered the field of consciousness under the term *anastomosis* as a means of accounting for the emergence or enlargement of another longitudinal line. The early investigators of the development of the venous system rarely figured these plexuses, and their schemata showing only the longitudinal hydrodynamic lines, still illuminate our text-books and adumbrate the subject. Recent workers give more complete figures (Lewis,⁶; Miller,⁸; Huntington and McClure,⁹):

The plexiform arrangement of the postcaval line disappears earlier, both in development and phylogeny, than is the case in the more peripheral regions. *Ornithorhynchus* alone shows the plexus in any marked degree in the postrenal cava; in *Echidna* it has almost disappeared. The determining factor in the formation of these large

⁶Miller, A. M., '03. "The Development of the Post Caval Vein in Birds." *Amer. Jour. Anat.*, Vol. II, No. 3. (See Fig. 5, page 289.)

⁹Huntington, G. S., and McClure, C. F. W., '07. "The Interpretation of the Variations of the Postcava and Tributaries of the Adult Cat, based on their Development." *Amer. Jour. Anat.*, Vol. VI, No. 3, page 33.

This paper was illustrated by reconstructions which have not yet been figured, showing clearly the plexiform nature of the periaortic vessels.

trunks, by the enlargement of a part of the plexus, we believe lies in the large volume of blood which must pass through the centrally placed vessels. The well-known facts of collateral circulation, following ligation, abundantly prove that a vein responds by growth to an increased flow of blood, that is, its size is determined by its drainage area. Evidently the vessels proximal to the heart have more blood to transmit than any of their tributaries and receive, therefore, a greater stimulus to growth. The hydrodynamic factor operates most intensely at the center, and the development of the venous trunks proceeds from the center toward the periphery by the enlargement of capillaries and plexuses along favorable lines and the resolution of the remaining reticulum into small tributaries. The considerable range in the variation of the post-cava appears due to the approximate parallelism of the channels about the aorta. When vessels inosculate at a very acute angle the freedom of the out-flow into the common trunk must be very nearly equal for both. When both have a common drainage area, as these vessels, it must be a very nice balance that determines which of them is to survive. In many cases it is some external factor, such as the pressure of a muscle, or the development of some organ, e. g., the mesonephros, or the migration of the kidney in the case of the postcardinal, which gives decision when the internal factors seem so nearly in equilibrium. The hydrodynamic lines once established, the plexus resolves itself into tributaries of small size, as in the case of the pelvic vessels.

It remains to determine, if possible, the origin and direction of the major hydrodynamic lines. The earliest vessels in the vertebrate appear as a capillary network which increases at the periphery by the formation of new capillaries in the growing region, while the central areas are constantly being resolved into larger vessels. Beautiful demonstrations of this reticulum have recently been given by Clark¹⁰ and Evans.¹¹ The development of the vessels in the chick's

¹⁰Clark, E. R., '09. "Observations on the Living Growing Lymphatics in the Tail of the Frog Larva." *ANATOMICAL RECORD*, Vol. III, No. 4.

¹¹Evans, H. M., '09. "On the Earliest Blood-vessels in the Anterior Limb Buds of Birds and their Relation to the Primary Subclavian Artery." *Amer. Jour. Anat.*, Vol. IX, No. 2.

blastoderm is too well known to require description, especially in the light of Thoma's¹² extensive work, but it illustrates admirably a number of points which we desire to emphasize; first, the capillary reticulum; second, the formation of veins outward from the center; and third, the presence of a continuous channel at the periphery—the vena terminalis. The drainage lines at first radiate from the center like the spokes of a wheel—that is, they correspond to the direction of the growth of the area vasculosa. Later a reduction in their number occurs and larger branching vessels are formed. This seems to be merely a case of the recession of the angle of confluence and the expression of the already cited tendency of V-shaped confluences to develop a Y formation. A very similar phenomenon occurs in the development of the middle cerebral in man. Mall's figures¹³ show the same changes from reticulum to reticulum with hypertrophy of its radial lines, corresponding to the radial growth or expansion of the pallium, and finally the emergence of the branched veins. The pelvic vessels show the same series of types. It would appear that the primitive hydrodynamic lines conform to the direction of growth. A further illustration is afforded by the early veins of the longitudinally growing body. Lewis¹⁴ has shown that the first veins in the rabbit are the umbilical and the precardinal, both of them longitudinal.

We regret that the important article of Thoma came into our hands too late to receive the attention it deserves in the body of our paper. In many places our observations overlap and our conclusions are closely similar. We would point out, however, that the material used is largely different. Thoma working on the chick's area vasculosa was able to demonstrate the emergence of vessels along hydrodynamic lines, proceeding centrifugally by the enlargement of some of the capillary channels and the reduction of others. That he appreciated the general application of this important observation is shown by the following excerpt: "Auch die doppelten Begleitvenen der Arterien des Menschen und die Entwicklung des Venenplexus weisen auf solche Besonder-

¹²Thoma, R., '93. "Untersuchungen über die Histogenese und Histomechanik des Gefäßsystems." 1893, Stuttgart.

¹³Mall, F. P., '04. "On the Development of the Blood-vessels of the Brain in the Human Embryo" Amer. Jour. Anat., Vol. IV, No. 1.

¹⁴Lewis, F. T., '02. "The Development of the Vena Cava Inferior." Amer. Jour. Anat., Vol. I, No. 3.

heiten hin, doch wäre es offenbar verfrüht, diese Formelgenthümlichkeiten, bei denen sicher noch andere Umstände mitwirken, hier ausführlicher zu erörtern."

This principle we have sought to apply to other areas. In the continuation of his paper he is interested mainly in the arterial system, while we have sought to apply certain simple mechanical views to the major venous lines. As regards the hydrodynamic factors themselves, while admitting freely the importance of Thoma's findings and the ingeniousness of his deductions, we have ventured to depart somewhat from his conclusions notably the first of his hydrodynamic laws. With the other two our paper, from its limited scope, is not concerned. This law is formulated by Thoma as follows: "Das Wachstum der Gefäßlichtung, d. h. das Flächenwachsthum der Gefäßwand ist abhängig von der Stromgeschwindigkeit des Blutes." It must be borne in mind that the conditions under which the arteries and veins develop are different as are the functions which they perform, and that, therefore, conclusions arrived at by the study of one system cannot be directly transferred to the other, as, for example, that in general the velocity of flow determines the size of the lumen; while this may hold true for the arterial system in itself, it is invalid in a comparison of artery and vein, e. g., compare the lumen of the aorta with that of the postcava. This rule would lead us to expect a larger lumen in the aorta than in the cava; the exact opposite is the case. And yet these vessels must transmit in one cardiac revolution the same volume of blood, unless congestion or anemia of their common area is to result. We are inclined to consider the volume the determining factor. Now the volume is the product of the pressure and cross section, the smaller tube will deliver in a unit of time the same volume as the larger under sufficiently increased pressure. Accordingly we find vessels adapted in two directions to supply the volume determined by metabolism of the tissues; first, under conditions of higher pressure, with thicker walls and smaller lumina; second, under conditions of lower pressure with thinner walls and greater lumina. The velocity of flow, we hold, to be conditioned by these moments, as in the adult by the difference between the *a tergo* and the *a fronte* factors.

In the chick of 36 hours (Fig. 11) is found an arrangement of veins closely parallel to the condition existing in the area vasculosa. A centrifugal formation of veins along the hydrodynamic lines which correspond to the direction of growth of the drainage area, and terminates peripherally in a reticulum, bounded by marginal vessels, the umbilical and postcardinal veins, which in this respect resemble the vena terminalis. Proceeding from the periphery to the center, that is, caudo-cephalad, we find first an abundant capillary reticulum, then an area where the reticulum has a somewhat ladder-like figure, the emerging cardinal and umbilical forming the

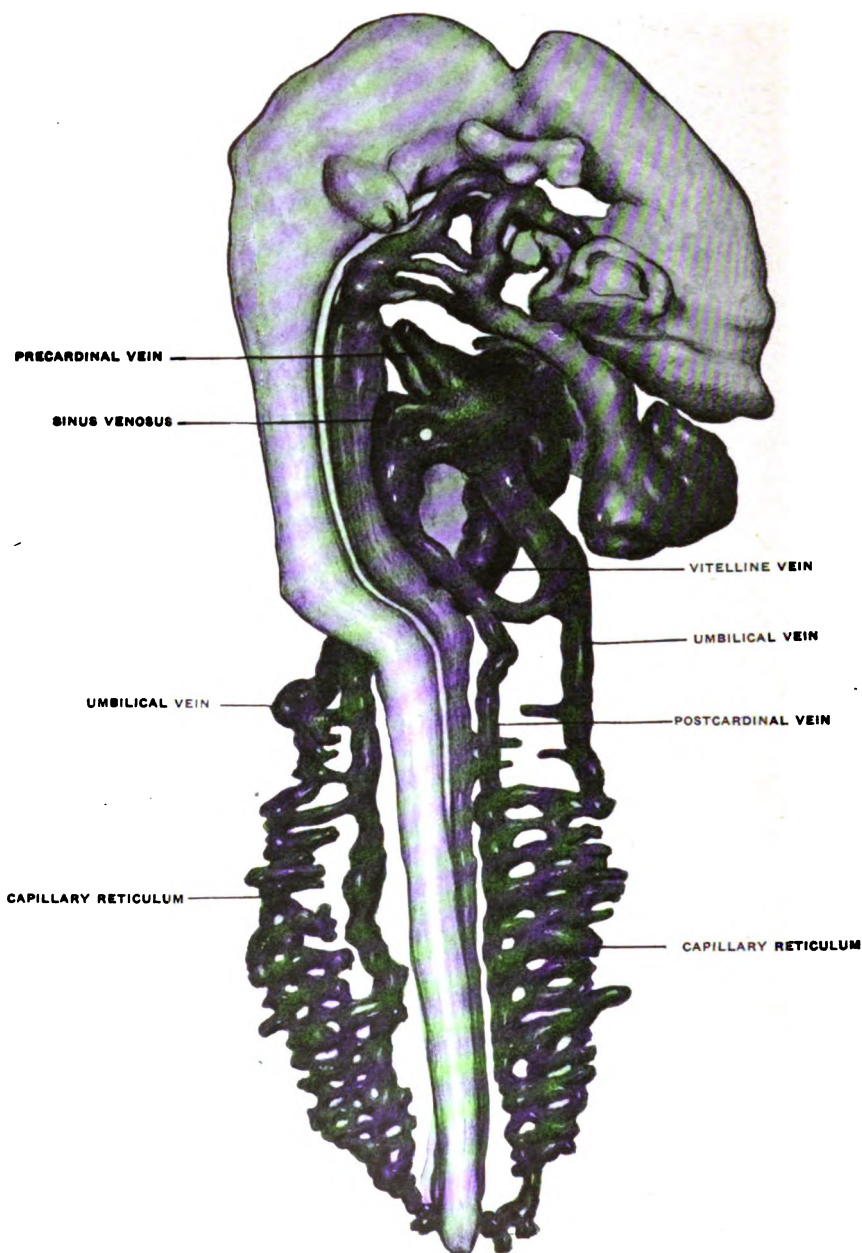


FIG. 11. Chick of the thirty-sixth hour. From a reconstruction in the study collection of the Department of Anatomy, Columbia University. Showing the character and disposition of the capillary reticulum between the umbilical and post-cardinal veins.

uprights, while the intervening reticulum assumes a transverse disposition. The longitudinal vessels respond by increasing growth to increasing function; their diameter is determined by the length of the area drained, that of the transverse vessels by its width, both in rough proportion to the volume of blood they carry and this in turn to their respective drainage areas. Finally we reach distinct areas with lateral tributaries, trunks having emerged along hydrodynamic lines by the solution of a plexus. The formation of a divide between the lines of the umbilical and postcardinal veins is really a simple example of the principle we tried to show as operative in the case of veins convergent at an angle. The marginal arrangement of this drainage system has been alluded to. At first the umbilicals predominate, later they largely lose their function as veins of the somatopleure and the postcardinals usurp their territory, and becoming united by a reticulum across the aorta form important elements in the periaortic plexus. Here is an obscure instance of the substitution of axial for marginal drainage. Owing to the relatively large volume of blood seeking return along these lines—from the trunk and posterior extremities through the cardinal, and from the allantois through the umbilical—the longitudinal are so accelerated in growth and so dominate the picture that their relation to the reticulum is masked. The phenomenon of deep axial drainage replacing a superficial marginal type which is earlier in time, appears also in the limbs, in the substitution of the axillary and femoral lines for the primitive *Rand-venen*, while in the tail the lateral caudal veins may possibly be a persistence of the marginal type. Their apparent connection with remnants of the umbilical line in marsupials lends color to this view. The general problem appears worthy of further investigation, especially with reference to the underlying mechanical factors.

We have made but little reference to external factors modifying the development of the venous system, both because they have in general received more attention than conditions of flow which it was our purpose to estimate, and because we believe them to be modifying factors only, acting upon otherwise determined hydrodynamic lines. We believe that the retention of multiple points of debouchment by

a trunk vein, of which the venous island or fenestra is a special case, must be explained in this way. It is a survival of a retrogressing plexus, but its retention increases the surface friction of the system. The mechanical factors we have instanced in the reduction of the plexus operate against its persistence, for in the case of a fenestra in a venous trunk, either the recession of the angle of confluence would tend to the fusion and absorption of the walls separating the arms of the loop, or else the arm that fell most nearly into the lines of the efferent and afferent vessels would have the freer in-let and out-let and so receive a greater stimulus to growth. An exact equilibrium, requiring that both arms should converge and diverge at the same angle to the parent trunk, or that one side of the loop should be favored by the entrant, the other by the emergent vessel in equal degree, could not be expected often to occur. One arm would increase, the other decrease, until the favored arm was lost in the continuity of the trunk, the other forming a minute tributary or two, or altogether retrogressing. Evidently an external factor must be sought in the motion of adjacent structures, favoring or impeding flow, now in one arm of the loop, now in the other. Obviously the passage of an artery or a nerve through a fenestra does not occasion the persistence of both of its arms. In the case of a muscle, the matter is different; for example, in *Ornithorhynchus*, the anastomosis lateral to the *psoas minor* affords escape for the blood when the *psoas* presses upon the dorsal plexus.

Our argument has, hitherto, been that veins develop out of a capillary reticulum under the influence of hydrodynamic factors. The genesis of the reticulum does not affect its reaction to these factors, yet if the argument which we have presented has validity, its eventual extension to the origin of the capillaries themselves out of inter-cellular spaces may not prove entirely mistaken. Such spaces serving as circulatory channels are described in a number of invertebrates.¹⁵ The flow through these spaces might be conceived to occasion a flattening of the surfaces impinging upon the blood stream—the inception of an endothelium, which would thus cease to be an

¹⁵Dahlgren and Kepner. "A Text-book of the Principles of Animal Histology." (See Figs. 134, page 151.)

entity and become merely a position modification of the mesenchyme. Its instability as a tissue-form after the ligation of a vessel is well known. The fact that the endothelium of the embryo spreads from the center to the periphery does not preclude the possibility that its characters are determined by its relation to the blood stream, for the flow is most rapid and voluminous at the center and consequently there should be sought its earliest and greatest effects. There also, the mesenchyme giving rise to the muscularis and adventitia receives its greatest stimulus. We have ventured upon the debatable and very controversial ground of the vascular endothelium, in order to point out that the vital problem of the veins concerns not the great vessels but the capillaries.

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THE EARLY DEVELOPMENT OF THE AORTIC ARCHES OF THE CAT, WITH ESPECIAL REFERENCE TO THE PRESENCE OF A FIFTH ARCH.

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WITH TWELVE FIGURES.

Through the investigations of Rathke, Hochstetter, and others the development of the aortic arches of the vertebrates in general is very well understood. The existence in the mammals, however, of a fifth aortic arch, lying between the systemic and pulmonic arches, has been a matter of recent discussion, and the work on this paper was begun with the view of investigating the conditions as they are in the cat. Consideration will be given to the papers dealing with a fifth arch in the mammals when this arch is dealt with in the following pages. An extensive general bibliography may be found in Hertwig's "Handbuch" following Hochstetter's article on "Die Entwicklung des Blutgefäßsystems."

The history of the arches in the cat was studied by means of wax reconstructions made after the method of Born at enlargements of sixty-six and forty diameters. Twenty-six embryos were examined, from 3.5 to 16 mm. in length, and sixteen reconstructed, of which ten are reproduced here. The reconstructions represent casts as it were of the lumina of the blood vessels and the cavity of the pharynx, and do not indicate the thickness of the walls or the character of the glandular structures developed from the branchial pouches. No attempt will be made to describe fully the development of the pouches, which are shown in the earlier stages to illustrate the consistent relations of the blood-vessels to the branchial arches.¹

¹O. Hertwig, Handbuch der vergleichenden und experimentellen Entwicklungsgeschichte der Wirbeltiere, Band III, Teil 2.

LIST OF MATERIAL STUDIED.

3 mm.	Series 188.	Columbia University Collection.
3 mm.	Series 45.	Princeton University Collection.
4.5 mm.	Series 93.	Columbia University Collection.
5 mm.	Series 47.	Princeton University Collection.
5 mm.	Series 11.	Princeton University Collection.
5.6 mm.	Series 110.	Columbia University Collection.
6 mm.	Series 84.	Columbia University Collection.
6 mm.	Series 126.	Columbia University Collection.
6 mm.	Series 127.	Columbia University Collection.
6.5 mm.	Series 131.	Columbia University Collection.
5 mm.	Series 30.	Princeton University Collection.
5 mm.	Series 31.	Princeton University Collection.
6.8 mm.	Series 103.	Columbia University Collection.
6.8 mm.	Series 105.	Columbia University Collection.
7 mm.	Series 137.	Columbia University Collection.
7 mm.	Series 138.	Columbia University Collection.
7 mm.	Series 2.	Princeton University Collection.
7.25 mm.	Series 13.	Princeton University Collection.
8 mm.	Series 3.	Princeton University Collection.
8 mm.	Series 5a.	Princeton University Collection.
9 mm.	Series 19.	Princeton University Collection.
10 mm.	Series 101.	Columbia University Collection.
11.5 mm.	Series 29.	Princeton University Collection.

In the youngest embryo examined (3 mm., Fig. 1), in which the pharyngeal membrane has not yet broken through, there is a single aortic arch, through which on each side the primitive heart communicates directly with the dorsal aorta. There are two well-defined branchial pouches on each side, which appear to be homologous with the first and second pouches of later stages. Between these two there are slight protrusions from the dorsal aorta, and an irregular outgrowth from the ventral aorta, as shown in Fig 1. This ventral outgrowth is of a very indefinite character, and has the appearance of a tissue-space which has become continuous with the ventral aorta in two places. An identical condition was found in another embryo of this litter, Series 188. Whether or not these cavities are to be regarded as tissue-spaces that are utilized in forming the second aortic arch cannot be discussed here; at any rate, they and the dorsal buds seem to be the ventral and dorsal anlagen of the second arch. Behind the second pouch also there is on each side an evagination from the dorsal aorta, the anlage of the third arch.

An embryo of 4.5 mm. (Fig. 2) shows the second and third arches completed, and the ventral anlage of the fourth arch extending caudad from the middle of the third arch. On the left side, a

dorsal as well as a ventral anlage of the fourth arch has appeared. From the distal end of the first arch a vessel has grown forward, and when this arch degenerates carries the blood directly forward from the dorsal aorta into the head region. This vessel constitutes that portion of the internal carotid artery which is developed in

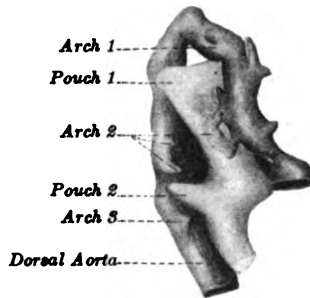


FIG. 1.—Reconstruction of the aortic arch system of a 3 mm. cat embryo. Series 45, Princeton University Collection. Right side. $\times 66$.

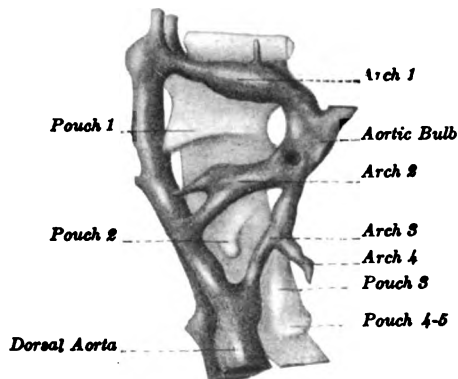


FIG. 2.—Reconstruction of the aortic arches of a 4.5 mm. cat embryo. Series 93, Columbia University Collection. Right side. $\times 50$.

front of the first aortic arch. A small aortic bulb has been formed by the coalescence of the ventral ends of the first and second aortic arches. Behind the third arch a large branchial evagination has made its appearance, and has already begun to divide into the third pouch and the swelling from which the fourth and fifth pouches are subsequently formed by a similar division.

In the next stage (5 mm., Fig. 3) the first two aortic arches are reduced in size, and from the ventral portion of the first arch capillaries extend out into the mandibular region. The ventral ends of the third arches have begun to fuse together, so that the aortic bulb is enlarged and shifted caudad. This is a stage in the progressive coalescence which takes place between the ventral ends of all the aortic arches, with the subsequent formation of a large aortic bulb.

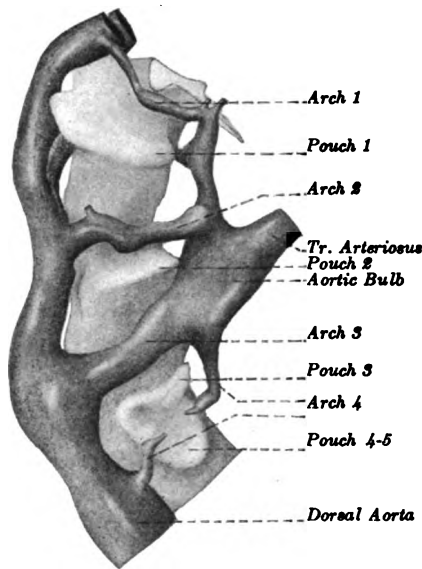


FIG. 3.—Reconstruction of the aortic arches of a 5 mm. cat embryo. Series 47, Princeton University Collection. Right side. $\times 50$.

The dorsal anlage of the fourth aortic arch is now present on both sides, and the separation of pouches 3 and 4-5 more distinct.

Fig. 4, of an embryo 5 mm. in length, shows the fourth arch completed. The first arch has lost its connection with the dorsal aorta, leaving a dorsal remnant which soon disappears. Just anterior to this remnant, and to the hypophysis which lies mesial to it, there is an anastomosis, not visible in the figure, between the two dorsal aortæ by means of a large cross-trunk, a peculiarity which was observed only in this embryo and in Series 31, another of the same

litter. The fusion of the ventral ends of the third arches has continued and now involves the bases of the fourth aortic arches. In this embryo (Fig. 4) the sixth arch makes its first appearance, as a spur extending caudad from the ventral portion of the fourth arch. The third pharyngeal pouch has become still farther separated from

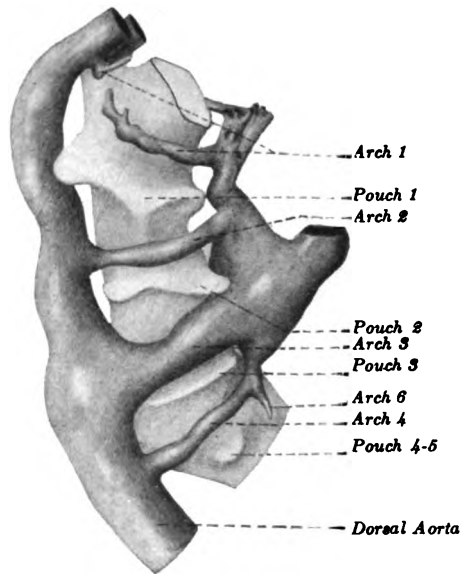


FIG. 4.—Reconstruction of the aortic arches of a 5 mm. cat embryo. Series 30, Princeton University Collection. Right side. $\times 50$.

the evagination caudal to it, which is a simple rounded structure that shows no evidence of division.

The 5 mm. embryo, Series 11 (Fig. 5), is a very important one, for it brings us to the question of a fifth aortic arch.² Before presenting the results obtained in the cat the observations in regard to this arch in other mammals will be briefly reviewed.

²In view of the differences observed in the relative development of their arches, it is probable that the measurements of the 5 mm. embryos (Ser. 11, 30, and 31) are incorrect.

Zimmermann³ (1889) described in the rabbit an artery arising from the truncus arteriosus and emptying into the dorsal aorta near the base of the pulmonic arch, separated from the systemic and pulmonic arches by distinct entodermal pouches. In an incomplete sheep series he found a vessel extending ventrad from the distal end of the pulmonic arch, but was unable to trace its ventral connection. The fifth arch as he described it in man represented a very different condition, as it arose from and terminated in the fourth arch, enclosing its middle third.

Tandler⁴ (1902) found in two human embryos a vessel extending from the ventral aorta to the distal end of the pulmonic arch. In the rat he interpreted an anastomosis between the fourth and pulmonic arches as a fifth arch, but could not discover a fifth pouch.

Lehman⁵ (1905) found in the rabbit irregular vessels arising from the fourth and pulmonic arches, and in the pig a somewhat similar condition, but found in one case a complete vessel from the ventral end of the fourth arch to the dorsal aorta. This vessel was connected by a short stem with the pulmonic arch, and was separated from the fourth and sixth arches by distinct branchial pouches.

Lewis⁶ (1906) in the rabbit and pig described only irregular vessels, and expressed the belief that none of these spurs or additional roots at the bases of the arches could be interpreted as a fifth aortic arch, and that the evagination described as postbranchial body is not serially homologous with the preceding pouches.

Locy⁷ (1906), commenting upon the condition of the fifth arch in the mammals, states his belief in the existence of a fifth arch. He

³W. Zimmermann. Ueber einen zwischen Aorten und Pulmonalbogen gelegenen Klemenarterienbogen beim Kaninchen. *Anat. Anz.*, Bd. IV, 1889. Rekonstruktion eines menschlichen Embryos. *Verh. Anat. Ges.*, 1889.

⁴Tandler, J. Zur Entwicklungsgeschichte der Kopfarterien bei den Mammalia. *Morph. Jahrb.*, Bd. 30, 1902.

⁵Lehmann, Harriet. On the Embryonic History of the Aortic Arches in Mammals. *Anat. Anz.*, Bd. XXVI, 1905.

⁶Lewis, F. T. The Fifth and Sixth Aortic Arches and the Related Pharyngeal Pouches in the Rabbit and Pig. *Anat. Anz.*, Bd. XXVIII, 1906.

⁷Locy, William A. The Fifth and Sixth Aortic Arches of Chick Embryos with comments on the condition of the same vessels in other Vertebrates. *Anat. Anz.*, Bd. XXIX, 1906.

thinks that its extreme variability and transitory character undoubtedly explain the lack of definite information regarding it in some of the forms, and notes the individual differences in those forms in which a complete arch has been described.

Soulié and Bonne⁸ (1908) in their paper on the arches of the mole describe a typical fifth aortic arch, arising separately from the

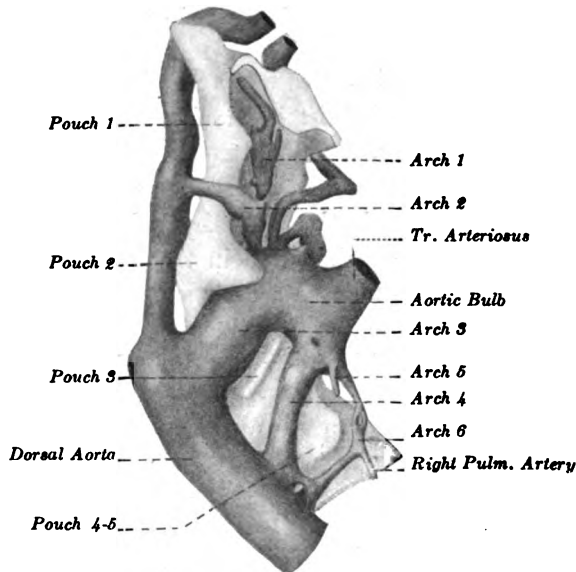


FIG. 5.—Reconstruction of the aortic arches of a 5 mm. cat embryo. Series II, Princeton University Collection. Right side. $\times 50$.

aortic bulb or in a common trunk with the pulmonic, and emptying in every case into the dorsal aorta in common with the pulmonic arch. This fifth vessel in the mole occupies a distinct branchial arch, which lies somewhat lateral to the fourth and sixth arches.

The typical mammalian fifth aortic arch appears thus to be a vessel which arises from the aortic bulb and empties into the pulmonic arch near its junction with the dorsal aorta. The development is

⁸Soulié, A., and Bonne, C. L'Appareil Branchial et les Arcs Aortiques de l'Embryon de Taupe. Journ. de l'Anat. et de la Phys., No. 1, 1908.

most complete in man and the mole, in which an unbroken arch is the rule; in the cat, as will be described in the following pages, and in the pig, the same type of development is followed, but a perfect arch would seem not to be produced ordinarily. In the rabbit the condition is still more rudimentary, and one must agree with Lewis that evidence of a fifth aortic arch in this form is wanting,

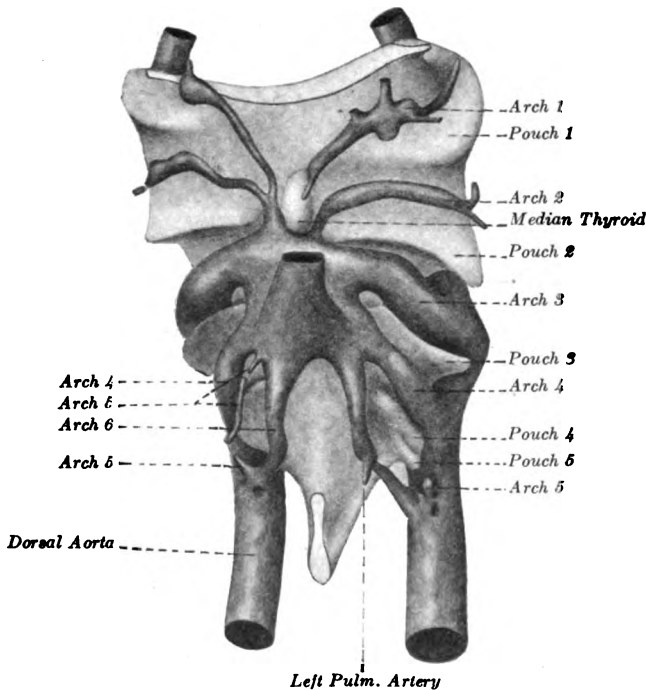


FIG. 6.—Reconstruction of the aortic arches of a 5.6 mm. cat embryo. Series 110, Columbia University Collection. Ventral view. $\times 50$.

while the observations on the sheep and the rat are still incomplete, as giving evidence for a vessel of the type described above.

A condition very similar to that occurring in man and the mole, but, in general, more rudimentary, was found by the writer in the cat. In embryo Series 11 (Fig. 5) on the right side a spur extends dorsad from the aortic bulb, between the fourth and pulmonic arches (arch 6). This spur occupies the position from which a fifth arch

would develop and resembles in all respects the anlagen from which the other arches arise. The sixth arch is complete, and gives off a short pulmonary artery on the right side. In addition to the spur of the fifth aortic arch, there is a short vessel connecting the dorsal ends of the fourth and sixth arches, very similar to the anastomosis between the two arches found in the rat by Tandler and to the vessel between the fourth arch and the root of the pulmonic in the pig described by Lehmann. On the left side there was to be found no

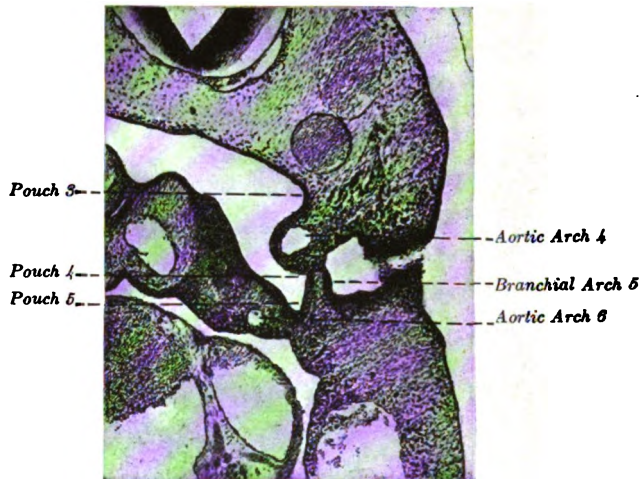


FIG. 7.—Photomicrograph of a transverse section through the fourth, fifth and sixth branchial arches of a 5.6 mm. cat embryo. Right side. Series 110. Columbia University Collection.

trace of a fifth aortic arch. The fourth and fifth pharyngeal pouches have not separated in this embryo and consequently the fifth branchial arch is not clearly marked out.

In an embryo of 5.6 mm. (Series 110, Fig. 6) the second aortic arches have lost their connection with the dorsal aorta, and their ventral remnants are disintegrating. There is on the right side a spur of the fifth arch from the aortic bulb similar to that shown in the preceding embryo, and in addition, a spur from the dorsal root of the pulmonic arch, with a blind vessel between them, almost con-

tinuous with the ventral spur, and running parallel to the arches on either side. Each pulmonic arch joins the dorsal aorta by three distinct roots, not clearly shown in the figure. On the left side two spurs project from the dorsal end of the pulmonic arch, the larger of which is directed ventrad between the fourth and fifth branchial pouches. The fourth or most caudal pharyngeal evagination has grown out, in its dorsal portion, into two divisions, the fourth and fifth branchial pouches, which are shown in section in Fig. 7, through the right side, and Fig. 8, through the left side. The photomicrographs show also the distinct character of the fifth branchial arch, and the two ectodermal grooves in the floor of the sinus precervicalis. The ventral portion of the fourth pharyngeal evagination remains undivided and as a result the fifth branchial arch is very short. This stage marks the highest development of the fifth aortic and branchial arches in the cat; in later stages the development is retrogressive.⁹

In embryo Series 138, 7 mm. in length (Fig. 9), the first aortic arches have entirely disappeared, and the second arches are mere stubs which break up into capillaries. There is no fifth aortic arch, but the fifth branchial arch is very clearly marked out by the ectodermal grooves on the outside, and as in Series 110 (Figs. 7 and 8) lies to the outer side of the fourth and sixth branchial arches. The dorsal end of the sixth aortic arch is very large, and on the right side shows a peculiar grooving which is suggestive of a division into two much longer roots than found elsewhere. In this and the pre-

⁹Since the completion of this paper, Tandler has published in the *Anat. Hefte*, 115 Heft (38 Bd., Heft 2), a careful description of the aortic arches and related pharyngeal pouches to be found in human embryos. His account agrees remarkably with mine. In man, however, the fourth and fifth pouches are derived from the *ventral* portion of the last pharyngeal evagination, and become more widely separated and distinct structures than in the cat. Correspondingly, the fifth aortic arch attains a more complete development. The pouches of the cat have been made the subject of a careful study by Henry Fox, whose article on "The Pharyngeal Pouches of the Mammalia" has appeared since the completion of the present work in the *Am. Jour. of Anat.*, Vol. VIII, No. 3. His results are entirely in accord with mine, although he makes no mention of a fifth pouch, which I interpret as a division of his "dorsal process of the fourth pouch." An indication of this separation into two pouches is to be seen on the left side in his Fig. 60.

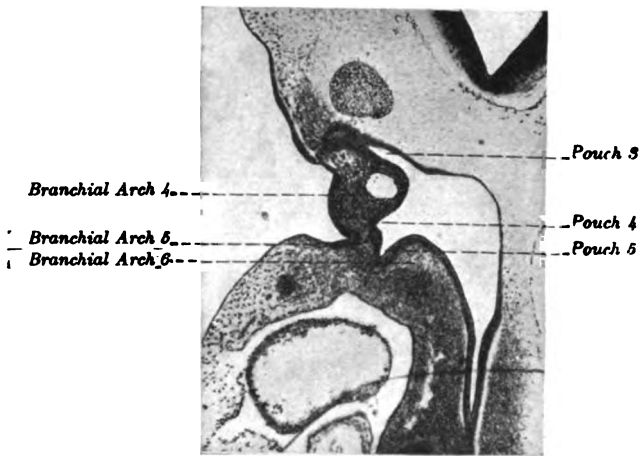


FIG. 8.—Same as Fig. 7. Left side.

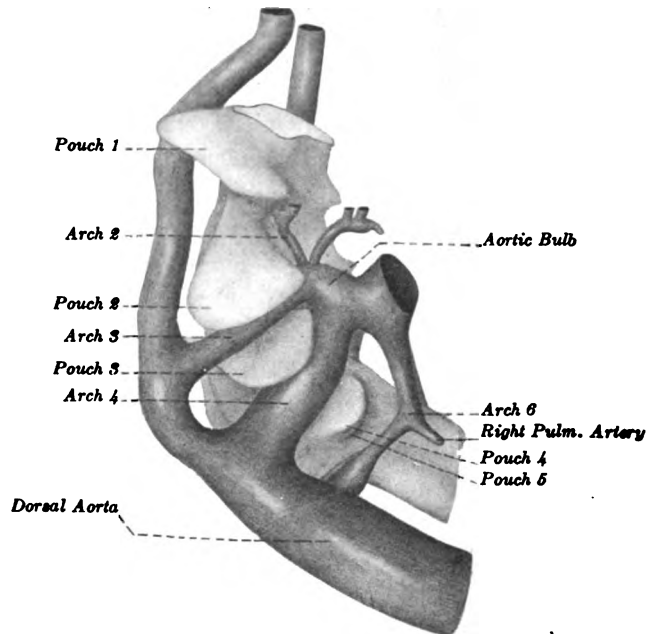


FIG. 9.—Reconstruction of the aortic arches of a 7 mm. cat embryo. Series 138, Columbia University Collection. Right side. $\times 50$.

ceding embryo the fourth and fifth branchial pouches are distinguishable, but their lumina are becoming obliterated, and their common connection with the pharynx cavity is being elongated and constricted off. Traces of the fourth pouch are to be found in embryos of 8 and 9 mm., but in later stages it apparently disappears completely.

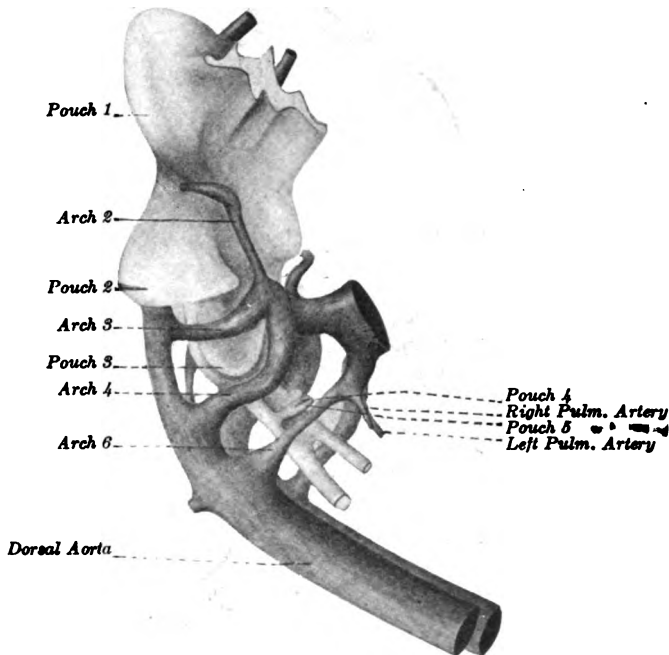


FIG. 10.—Reconstruction of the aortic arches of a 9 mm. cat embryo. Series 19, Princeton University Collection. Right side. $\times 30$.

In an embryo of 6 mm. (Series 129, not figured) the dorsal root of the sixth aortic arch is very large, as in the Series 110 (Fig. 6), and a similar but longer spur arises from the base of the left pulmonic arch and ends blindly in the substance of the fifth branchial arch.

Whatever the significance of the arterial spurs in the cat may be, it is certain that we have here, outlined by the five entodermal pouches on the inside and the corresponding ectodermal grooves on

the outside, six branchial arches. The fifth is a diminutive structure and occupies a position relatively dorsal and lateral to the other branchial arches. The facts observed point to the conclusion that ordinarily no fifth aortic arch is completely developed in the cat; and it seems more than probable that the incomplete development and

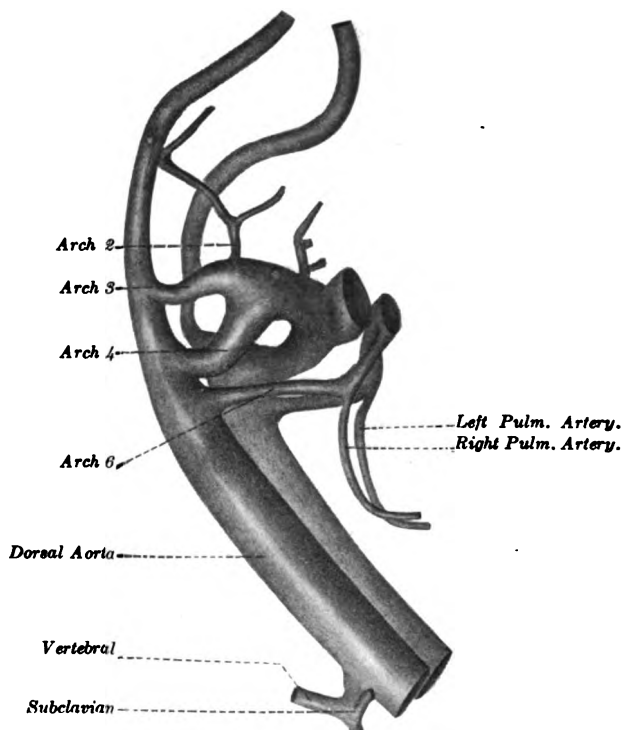


FIG. 11.—Reconstruction of the aortic arches of a 10 mm. cat embryo. Series 101, Columbia University Collection. Right side. $\times 28$.

uncertain character of the fifth aortic arch is merely an expression of the incomplete development of the fifth branchial arch. It may well be that the anastomoses and irregular roots about the base of the pulmonic arch which have been so generally described in the mammalia are evidence of an assimilation of the fifth aortic arch into the pulmonic, beginning at their dorsal extremities.

The ventral anlage of the sixth aortic arch appears first, as a bud from the ventral end of the fourth arch (Fig. 4). Somewhat later a dorsal bud grows out from the mesial side of the dorsal aorta, and the completed arch pursues a curved or bent course around the fourth and fifth pouches. The dorsal root of the pulmonic arch in every case, from its first appearance until after the buds of the pulmonary arteries arise, was found to be pierced by two or more "islands." The significance of this has been referred to above. At

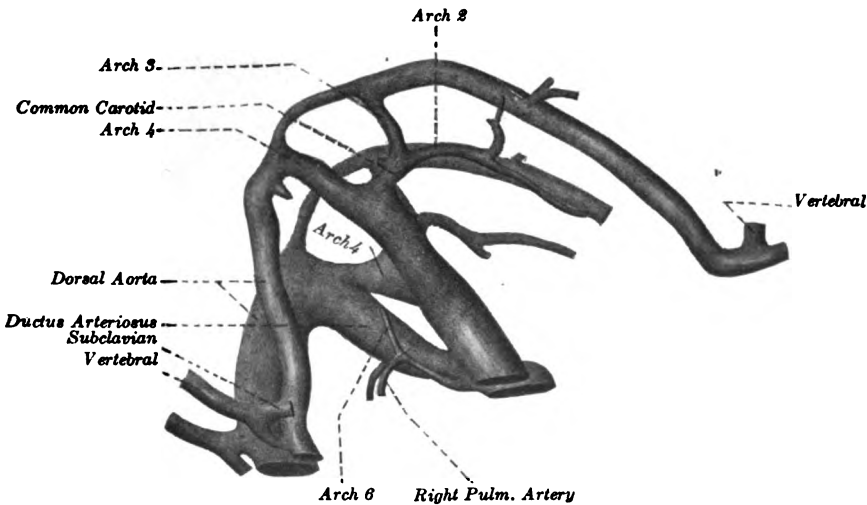


FIG. 12.—Reconstruction of the aortic arches of an 11.5 mm. cat embryo. Series 29, Princeton University Collection. Right side. $\times 27$.

about the time that the rudiments of the fifth aortic arch appear, (Figs. 5 and 6) the pulmonary arteries begin to develop from the middle of the sixth or pulmonic arches. Their development is very similar to that described by Bremer¹⁰ (1901) in the rabbit. They grow caudad, following the curve of the dorsal aorta, on each side of the trachea. The aortic bulb now begins to lengthen out between the fourth and sixth arches, and to divide into the short systemic

¹⁰Bremer, J. L. On the Origin of the Pulmonary Arteries in Mammals. Am. Jour. Anat., Vol. I.

and pulmonic trunks (Figs. 9, 10 and 11). In this process, the pulmonic trunk is twisted from right to left, and so comes to lie on the left side of the systemic trunk. At the same time the ventral ends of the two pulmonic arches are brought into contact, and they fuse together up to the point where the pulmonary arteries are given off (Figs. 11 and 12).

The later history of the aortic arch system is too well known to require any comment, and I leave the description at this point.

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THE PHYLOGENY OF THE FACIAL NERVE AND CHORDA TYMPANI.¹

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WITH SIX FIGURES.

The structure of the human nervous system is so complex and is modified in so many ways from the normal vertebrate type that the interpretation of its morphology and function often becomes a matter of serious disagreement. The situation is further complicated by the fact that experimentation, open to the student of lower animals, is necessarily barred in an investigation of the highest. It is largely owing to these considerations that the question of the innervation of the tongue for the sense of taste is even now, after seventy years of study, one of the most disputed points in human anatomy. This discussion is for the purpose of calling attention to the ease with which a careful analysis of the data furnished by phylogenetic history will elucidate the most vexed questions of human morphology.

The tongue is innervated by two sensory nerves, the glossopharyngeal and the lingual. While the former takes its course direct from the posterior part of the tongue to the petrosal ganglion, the latter is joined shortly by the chorda tympani from the facial nerve. (Fig. 6.) It would seem that the question as to which of these nerves fur-

¹Address given before a joint meeting of the Chicago Neurological Society and the University of Chicago Biological Club, March 30, 1909.

nishes the fibers for taste could be easily settled by their dissection in the adult, by sections of embryological material or by the observations made in clinical or other pathological cases. Such studies have, however, led to the most diverse results. Since the time of the researches of Claude Bernard in 1843 most authorities have been agreed in assigning the fibers for taste for the anterior part of the tongue (one-third to four-fifths) to the chorda tympani and denying their presence in the lingual above its junction with the chorda. Lussana, Wolf and Halban found that section of the chorda led to the loss of taste in the anterior part of the tongue while Blau obtained taste sensations by stimulation of the same nerve. Disease of the middle ear, affecting the chorda, after the observations of Urbantschitsch, Schlichting, Kiesow and Nadoleczny and Köster, likewise causes loss of taste. Destruction of the lingual V above its junction with the chorda almost invariably is without effect on the sense of taste, although Schiff in 1887 and recently Köster, consider that a part of the taste fibers go by way of the lingual either directly into the Gasserian ganglion or into the otic and thence to the brain.

There is likewise considerable unanimity in regard to the source of the taste fibers for the posterior part of the tongue. The work of Dana, Pope, Cassirer, Zander, etc., demonstrates conclusively that these belong to the glossopharyngeal, the lingual IX. Most authors are agreed that these fibers originate from cells in the petrosal ganglion and connect directly through the sensory IXth root with the fasciculus solitarius. Some few, as noted in Fig. 5, trace the glossopharyngeal fibers, however, into the brain by way of Jacobson's nerve and the small superficial petrosal to the trigeminus. Such a view is given little weight at present. The controversy, then, centers on the course which the taste fibers from the anterior part of the tongue take after they enter the facial nerve from the chorda tympani. The earlier workers, such as Claude Bernard, Lussana, Duchenne and Vulpian, believed that these fibers took the most obvious course and entered the brain through the pars intermedia of Wrisberg. Clinicians in removal of the Gasserian ganglion or resection of the second or third ramus of the trigeminus for facial neuralgia often noted a complete loss of taste on the anterior part of the tongue of the same side.

Similar conditions were observed in cases of lesions affecting these nerves. Many such cases have been described, notably those by Erb, Ferguson, Gowers, Salomonsohn, Turner, Senator, Ziehl, Kron, etc. These cases have been so numerous and have been supported by such a weight of authority that even now the most widely accepted course for the chorda taste fibers is by way of the fifth nerve. Men holding this view differ, however, as to whether the taste fibers enter the brain by way of the maxillaris or the mandibularis branch of the trigeminus and likewise as to the pathway by which they reach these rami from the facial trunk. That most generally accepted traces the chorda fibers into the geniculate ganglion, thence through the great superficial petrosal and Vidian nerve to the sphenopalatine ganglion and thence into the maxillaris. Another course advocated is by way of the geniculate ganglion, the anastomotic branch to the small superficial petrosal, thence to the otic ganglion to the mandibularis nerve. It should be noted that practically all these cases rest upon clinical observations of pathological cases. As Scheier ('95) observes, many of these presented chronic lesions which are rarely local and might easily affect other nerve roots or ganglia. The same is true with the operations for removal of the Gasserian ganglion particularly as performed by the Hartley-Krause method. Few of the cases, moreover, were carefully studied for a long period of time by trained observers. The importance of this will appear later.

There are many cases recorded in opposition to this interpretation and it must be argued that a large number of such cases of removal of the Gasserian ganglion without interference with taste negative any number of cases accompanied by loss of taste. If the ganglion can be removed in its entirety without loss of taste the taste fibers certainly cannot go through it. Brunns, Tooth, Thomas, Tiffany, Frankl-Hochwart, and Fasola all note such cases. The most convincing, however, is the report of Cushing ('03) who removed the Gasserian ganglion completely in eleven cases and partially in two. Observations on the sense of taste were made in practically all the cases before operations. There was a temporary diminution or loss of taste in most of the cases, but in all but one taste returned eventually. The exception was under observation for only six days after

the operation. These results offer the strongest kind of evidence that the taste fibers for the anterior part of the tongue do not enter the brain by the way of the trigeminal nerve. Probably in the first cases noted other nerves were affected or else the cases were not under observation for a sufficiently long time.

Some recent experimental work on the lower vertebrates (Sheldon, '09) indicates that these discrepancies may be due to another cause: viz., that the nerves of general sensation, as found in the trigeminal nerve, for instance, react to certain kinds of chemical stimuli. Under such conditions, therefore, destruction of the Gasserian ganglion or of the lingual above its junction with the chorda might affect what we call the sense of taste.

Of course it is possible that the taste fibers enter the brain by way of the glossopharyngeal nerve. Such a course has been advocated by Carl, Herman, and Cassirer, for instance. The usual course advocated is by way of the chorda tympani, geniculate ganglion, ramus anastomoticus to the small superficial petrosal and thence into the plexus tympanicus and Jacobson's nerve to the petrosal ganglion. Another course suggested is by way of the lingual nerve into the otic ganglion and thence through the small superficial petrosal into Jacobson's nerve. While there is some anatomical evidence that there are fibers in the small superficial petrosal running in the direction indicated, there is little support to the view that these are taste fibers from the chorda tympani. The fibers certainly could not be derived from the geniculate ganglion as will be pointed out later, and there is no conclusive evidence that glossopharyngeal fibers enter the chorda or the lingual from the otic as Carl advocates. If the chorda fibers do not enter the brain through the fifth or the ninth nerve they must pass by way of the seventh. The situation here is complicated by the fact that clinicians generally find no interference with taste in lesions of the facial nerve in facial palsy, provided the lesions are centrad of the geniculate ganglion. Lesions or fractures peripherally of the ganglion in the temporal bone usually destroy taste in the anterior part of the tongue on the same side. Such evidence is presented by Wachsmuth, or more recently and fully by Köster, Rosenfeld, Kopczynski and Scheiber. It may be pointed out here, however, that the evidence

is not conclusive in these cases that the *portio intermedia* is involved. It might easily happen that the motor root is destroyed without injury to the sensory. This is supported by the large number of cases of destruction of the facial centrad of the ganglion involving the sense of taste on the anterior part of the tongue. Such cases are cited by Claude Bernard, Brunns, Lehman, Scheier, Panski, Donath, etc. Summarizing the clinical and other pathological cases we may say that the evidence is quite conclusive to the effect that taste fibers do not enter the brain by way of the fifth nerve, equally conclusive that the fibers from the anterior part of the tongue do not enter the ninth nerve and inconclusive so far as the *pars intermedia* is concerned.

So far as the innervation of the soft palate for taste is concerned there is much difference of opinion. The weight of evidence however, as Dixon points out, is to the effect that it is innervated through fibers from the geniculate ganglion through the great superficial petrosal, the sphenopalatine ganglion and the palatine nerves. Part of these fibers may, however, come from the glossopharyngeal nerve through Jacobson's nerve and the anastomotic branch from the tympanic plexus into the great superficial petrosal.

Writers who deny that the taste fibers for the chorda originate from the geniculate ganglion usually argue that the ganglion is sympathetic and may be concerned with fibers of that type found in the lingual. There is little doubt that the chorda contains sympathetic fibers for the submaxillary gland. Sympathetic fibers are also undoubtedly present in the glossopharyngeal, the superficial petrosal nerves and Jacobson's nerve. Part of these fibers are probably postganglionic with their cells of origin in some of the many sympathetic ganglia of this region; on the other hand a large proportion of such fibers found in the chorda tympani and associated visceral nerves are without question of the preganglionic type with their origin in the brain. Such include visceral efferent fibers of the secretory or excito-glandular type and vaso-motor fibers. The presence of such fibers, common to all the visceral nerves, in the *pars intermedia* of Wrisberg, cannot, therefore, be sufficient ground for assuming that this root or the geniculate ganglion are exclusively sympathetic.

Embryological and histological studies give more positive results.

Alexander ('02) found loss of taste after degeneration of the geniculate ganglion, which would show that the chorda fibers take their origin from it. From the time of His it has been known that the course of conduction in nerves can be demonstrated through knowledge of their method of growth; that is, an efferent nerve grows out from the brain while an afferent nerve grows, both toward the brain, and peripherally from its ganglion. His, Dixon and Streeter show conclusively that the facial is a mixed nerve, motor and sensory, and that its sensory part, the pars intermedia of Wrisberg, and the geniculate ganglion are similar in structure with the sensory parts of other nerves. Retzius, Martin, von Lenhossék and Ramón y Cajal, all working on mammals, have shown that the geniculate ganglion conforms to the cerebro-spinal rather than to the sympathetic type. It possesses the same kinds of cells as do other ganglia of the central nervous system and these cells send their processes both into the brain and peripherally. Roller, Turner, Huguenin, van Gehuchten, Ramón y Cajal and many others trace these central fibers into the fasciculus solitarius, known to be the center for taste in the human brain. Alexander obtained a peripheral degeneration of both the chorda and the great superficial petrosal. Sapolini traced fibers from the geniculate ganglion into the chorda, von Lenhossék believed that such was the course of the fibers, Weigner traced part of these fibers into the great superficial petrosal, Ramón y Cajal did likewise, while Dixon and Streeter found that both this and the chorda arise as outgrowths of the geniculate ganglion. This evidence shows that the geniculate ganglion is not sympathetic but cerebro-spinal in type, that its cells join centrally the taste centers of the medulla oblongata, and that its peripheral outgrowths form the chorda tympani and the great superficial petrosal nerves. Dixon shows that at the fifth week in the human embryo this latter nerve is free from any anastomoses with the fifth and that if any fibers grow into it from the fifth they must do so at a very late date. The anatomical evidence is, therefore, conclusive that the fibers for taste for the anterior part of the tongue are derived from the geniculate ganglion and enter the brain through the pars intermedia of Wrisberg.

The question now arises as to the extent to which comparative neurology will clarify the question. It has been noted that the fas-

ciqulus solitarius, the central connection of the fibers from the geniculate ganglion, is likewise the terminus for the taste fibers of the ninth nerve and is, therefore, the center for taste in man. Comparative studies show that the facial muscles of man are derived from the musculature of the hyoid arch of the lower vertebrates; the facial is, therefore, the nerve of the hyoid segment, just as the ninth is the nerve for the first posthyoidean segment. Such studies have also shown that although the tongue musculature has grown forward from the postbranchial segmented mesoderm that the sensory surfaces of the tongue in man belong to more rostral segments. The case is, simply, that the sensory surfaces involved retain their primitive innervation with only a slight shifting while more caudal muscles grow forward when the tongue evolves in phylogenetic history. We, therefore, find that the mucous surface of the posterior part of the tongue in man belongs to the first posthyoidean segment or that of the ninth nerve, while the anterior mucous surface of the tongue is a part of the hyoidean and mandibular segments, or the segments of the facial and trigeminal nerves. It is known also that the Eustachian tube of mammals corresponds to the spiracular cleft of fishes in a general way, although other structures also enter into the formation of the Eustachian tube. In man the chorda passes over the tympanic cavity, but underneath the auditory ossicles. It has, therefore, long been considered a pretrematic or prebranchial nerve, although Froriep held the opinion that it is postbranchial. In 1904 Emmel, however, found that at an early stage the mammalian chorda passes beneath the spiracular cleft or primitive Eustachian tube and that its pretrematic position is taken up later. The nerve is, therefore, posttrematic.

The facial nerve of the lower vertebrates, leaving out of consideration the lateral line component of the neuromasts which is only apparently a part of the facial, is in every case a mixed motor and sensory nerve. As has been noted before, it is the nerve of the hyoid segment. As the musculature of this segment is, in all lower forms, derived from the lateral mesoderm, its motor component, as in man, is visceral motor. Primitively, as Johnston has shown in the lamprey, the facial nerve contained two sensory components, that is, it possessed fibers for the innervation of the skin for general sensation and

the region of the spiracle, roof and floor of the mouth for taste and other visceral sensation. In most forms above the cyclostomes the evidence is strong that the only sensory component remaining is the visceral, innervating mucous surfaces, while cutaneous sensation for the hyoid segment is served by fibers from the trigeminal or vagus nerves. J. Ramsey Hunt has, however, brought forward evidence to show that in man a part of the general sensory system of fibers still remains in the facial; shown, for instance, by the persistence of tactile sensation on the anterior part of the tongue after section of the lingual above its junction with the chorda. In every carefully studied example among the lower vertebrates all taste buds in front of the glossopharyngeal segment are innervated through visceral sensory fibers from the facial nerve. They are likewise all derived from the geniculate ganglion and always end in the brain in the fasciculus solitarius which is, as has been noted, the center for taste in man.

Taking up the different groups of lower vertebrates more in detail the situation is made clearer. No attempt will be made, however, to consider the many mooted questions as to the comparative morphology of the different rami of the facial already ably discussed by Herrick, Cole, Coghill, etc. In the selachians, as will be noted from Fig. 1 (*Chlamydoselachus anguineus*), the facial contains the usual motor component, the ramus hyoideus for the hyoid musculature. There is a small component for the skin, derived, however, from the trigeminus nerve in all probability, through the anastomotic rami from the Gasserian ganglion. There are several rami for the sense of taste. Close to, or else arising directly from the geniculate ganglion is the palatine nerve for the mucosa of the roof of the mouth. Either from this or from the main trunk, slightly more distad are given off prespiracular or pretrematic rami. These innervate the spiracle and occasionally a part of the floor of the mouth. Descending with the main branch of the facial, the hyomandibular, is a large sensory component for the mucosa of the floor of the mouth rostrad, the mandibularis internus. This is evidently the homologue of the chorda tympani. Practically all selachians, as is shown by Cole, Strong, Ewart, Green, Jackson and Clarke and other workers, exhibit these conditions. We may, therefore, say that in this group the

sensory fibers of the facial serve the sense of taste of the roof of the mouth through the palatine rami, and the floor of the mouth rostrad through the pretrematic, and particularly the mandibularis internus.

In teleosts (Fig. 2, *Menidia*; Fig. 3, the cod) conditions are quite similar. The motor nerve, the ramus hyoideus, innervates the muscles of the hyoid arch, accompanied by a cutaneous branch from the Gasserian ganglion. A visceral sensory palatine arises from cells in the geniculate ganglion for the taste buds of the roof of the mouth; a large posttrematic ramus, the mandibularis internus innervates the floor, including the mucosa over the bones of the hyoid arch. A few visceral sensory fibers in *Menidia* leave the geniculate ganglion with the maxillaris for the upper lip and mucous lining of the upper jaw. The glossopharyngeal nerve here, as in higher forms, sends a lingual branch to the taste buds of the floor of the mouth. In the cod, as shown in Fig. 3, a branch from the petrosal ganglion of the ninth nerve, Jacobson's anastomosis, joins the posterior palatine nerve which largely distributes to the mucosa of the roof of the mouth. In *Pleuronectes*, as shown by Cole, there is a similar anastomosis. We know, from Dixon, Streeter, Ramón y Cajal, etc., that the origin of the great superficial petrosal of man is similar to that of the palatine VII in fishes. It is interesting to note that in fishes there exists an anastomosis from the ninth quite similar to that between Jacobson's nerve and the great superficial petrosal in man. It should be emphasized, however, that such an anastomosis is absent in many cases, as in the selachians and *Menidia*, so that the palatine VII in fishes is actually a derivative of the facial. Jacobson's anastomosis of fishes and Jacobson's nerve in man are apparently both palatine or pharyngeal rami of the ninth nerve carrying taste fibers for the roof of the pharynx.

An important special case is to be observed in the catfishes. Herick has shown that the outer skin of *Ameiurus* is covered with taste buds similar to those in the mouth. He has likewise shown, through extensive and painstaking experiments, that the fishes react to sapid substances on stimulation of these external taste buds in exactly the same way that they do when such substances come in contact with the mouth. In these fishes the external as well as the usual internal

taste buds are innervated through the facial nerve. Many special rami are developed for this purpose, leading to an enormous hypertrophy of the nerve and its center in the brain, the fasciculus solitarius.

In the amphibia conditions vary somewhat, but are essentially similar to those in fishes. Cutaneous fibers may be present in the VIIth but if so are derived from the Xth by way of a communicating branch. The ramus hyoideus in all amphibia is homologous with the motor facial of the fishes and man. A palatine ramus from the geniculate ganglion is always present and in the Urodela is joined by Jacobson's anastomosis, the fibers innervating taste buds in the roof of the mouth. The taste buds of the anterior part of the mouth are innervated by a nerve, called the ramus alveolaris in the Urodela and the mandibularis internus in the frog. It is, in both cases, derived from the geniculate ganglion as in the fishes. It is said to be, however, postspiracular or posttrematic in the Anura and pretrematic in the Urodela. (See Coghill, '02.) The origin and the region innervated are the same in both cases and it is without doubt the functional equivalent of the chorda tympani. The posterior part of the tongue is innervated by the lingual IX as in man.

In all these cases it will be noted that there are present the same three rami of the trigeminus as in man. There are, likewise, in the amphibia as in man, anastomoses between the terminal rami of the mandibularis and the nerves for taste for the rostral part of the tongue.

It is evident from the foregoing that the facial of lower vertebrates is both sensory and motor; that its motor portion is homologous with the facial proper in man; that its sensory portion through nerves homologous with the chorda tympani of man innervates the taste buds of a region comparable to the anterior part of the human tongue and that another branch of this same sensory element of the nerve, the palatine, is homologous with the great superficial petrosal of man. The evidence of comparative neurology, therefore, offers the strongest possible confirmation of the view that the chorda tympani of man is the nerve for taste for the anterior part of the tongue and that its fibers are derived from the geniculate ganglion, entering the brain

through the pars intermedia of Wrisberg. It also indicates that the great superficial petrosal nerve, like its homologue, the palatine, carries the fibers for taste for the roof of the mouth, and therefore innervates the taste buds of the soft palate through the palatine nerves from the sphenopalatine ganglion.

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EXPLANATION OF FIGURES.

It will be noted that legends accompany the figures, indicating that the rami which are crosshatched are general sensory; those in black, visceral and those blocked in, motor. The term "general sensory" as used here refers to fibers of the general somatic sensory type; "visceral," to fibers of the visceral sensory type and also to preganglionic visceral motor fibers of the sympathetic system while the "motor" fibers are those of the visceral motor type specialized for the innervation of the branchiomic striated musculature.

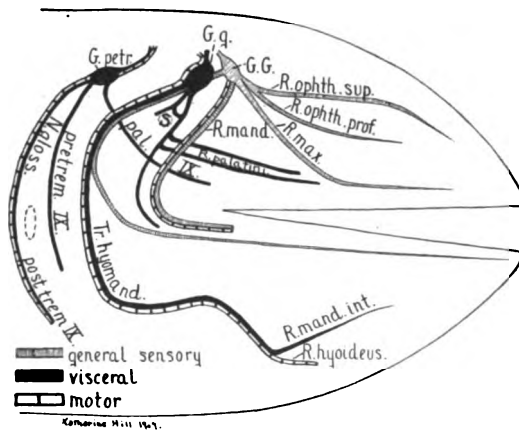


Fig. 1.

Diagram of the trigeminal, facial and glossopharyngeal nerves in *Chlamydoselachus anguineus*. (Modified from O. A. Merritt Hawkes.) All of the nerves of the lateralis system have been omitted. G. G., Gasserian ganglion; G. g., geniculate ganglion; G. petr., petrosal ganglion; N. gloss., glossopharyngeal nerve; pal. IX, palatine ramus of the IX; pretrem. IX, pretrematic ramus of the IX; posttrem. IX, posttrematic ramus of the IX; R. hyoideus, ramus hyoideus VII; R. mand., ramus mandibularis V; R. mand. int., ramus mandibularis internus VII; R. max., ramus maxillaris V; R. ophth. prof., ramus ophthalmicus profundus V; R. ophth. sup., ramus ophthalmicus superficialis V; R. palatini, palatine rami of the VII; S., spiracle; Tr. hyomand., truncus hyomandibularis VII.

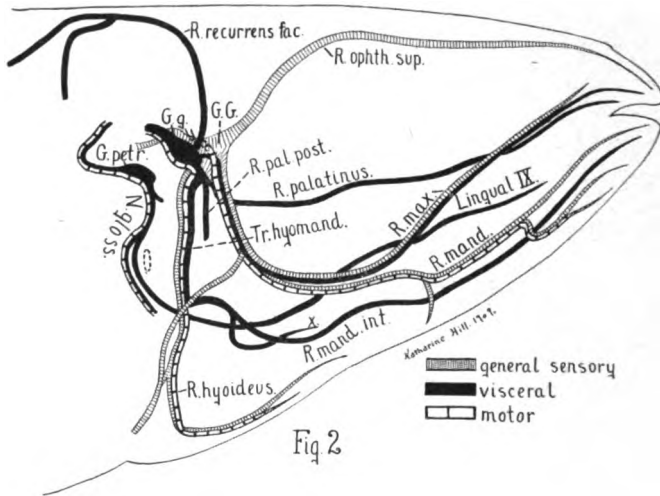


Diagram of the trigeminal, facial and glossopharyngeal nerves in *Menidia*. (Modified from C. Judson Herrick.) Laterals components omitted. G. G., Gasserian ganglion; G. g., geniculate ganglion; G. petr., ganglion petrosus; N. gloss., glossopharyngeal nerve; R. hyoideus, ramus hyoideus VII; R. mand., ramus mandibularis V; R. mand. int., ramus mandibularis internus VII; R. max., ramus maxillaris V; R. ophth. sup., ramus ophthalmicus superficialis V; R. palatinus, palatine VII ramus; R. pal. post., posterior palatine VII ramus; R. recurrens fac., ramus recurrens VII. This nerve innervates taste buds on the outer surface of the body and is the portion of the facial so enormously hypertrophied in the siluroids. Tr. hyomand., truncus hyomandibularis VII; x, branch of the mandibularis internus for the mucosa over the bones of the hyoid arch. The general sensory fibers in the hyomandibular trunk are derived from the Gasserian ganglion.

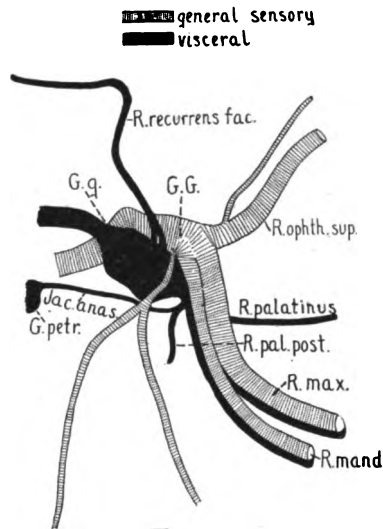


Fig. 3.

Diagram showing the trigeminal-facial complex in the cod. (Modified from C. Judson Herrick.) Laterals and motor components omitted. The anastomosis between the petrosal ganglion and the palatine rami is to be noted especially as such an anastomosis occurs somewhat similarly in man, between Jacobson's or the tympanic nerve and the great superficial petrosal. G. G., Gasserian ganglion; G. g., geniculate ganglion; G. petr., ganglion petrosum; Jac. anas., Jacobson's anastomosis, the pharyngeal or palatine ramus of the IX; R. mand., ramus mandibularis V; R. max., ramus maxillaris V; R. ophth. sup., ramus ophthalmicus superficialis V; R. palatinus, ramus palatinus VII; R. pal. post., ramus palatinus posterior VII; R. recurrens fac., ramus recurrens VII. (See explanation of Fig. 2.)

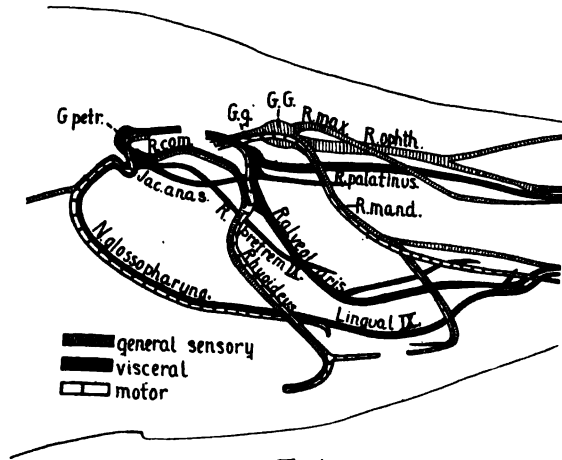


Fig. 4

Diagram of the trigeminal, facial and glossopharyngeal nerves of *Amblystoma tigrinum*. (Modified from Coghill.) Lateralis component omitted; petrosal ganglion separated from the vago-glossopharyngeal complex. The general sensory fibers in the glossopharyngeal and hyoid nerves are derived from the vagus root. G. G., Gasserian ganglion; G. g., geniculate ganglion; G. petr., ganglion petrosus; Jac. anas., Jacobson's anastomosis. (See explanation of Fig. 3) N. glossopharyng., nervus glossopharyngeus; R. alveolaris, ramus alveolaris VII, the functional equivalent of the chorda tympani in man; R. com., ramus communicans IX-X ad VII; R. hyoideus, ramus hyoideus VII; excluding the vagal fibers, the homologue of the facial proper in man; R. mand., ramus mandibularis V; R. max., ramus maxillaris V; R. ophthalmicus V; R. pretrem. IX, ramus pretrematicus IX.

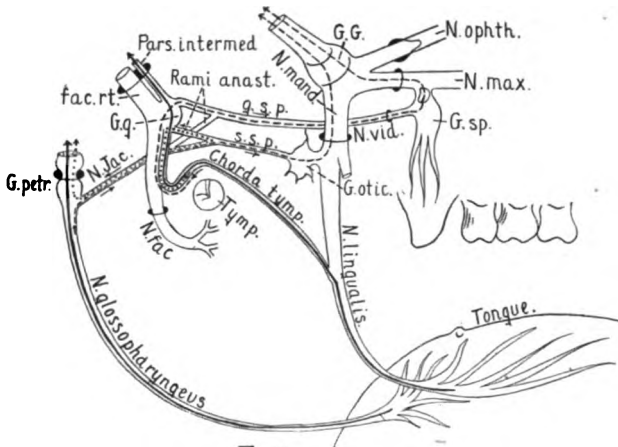
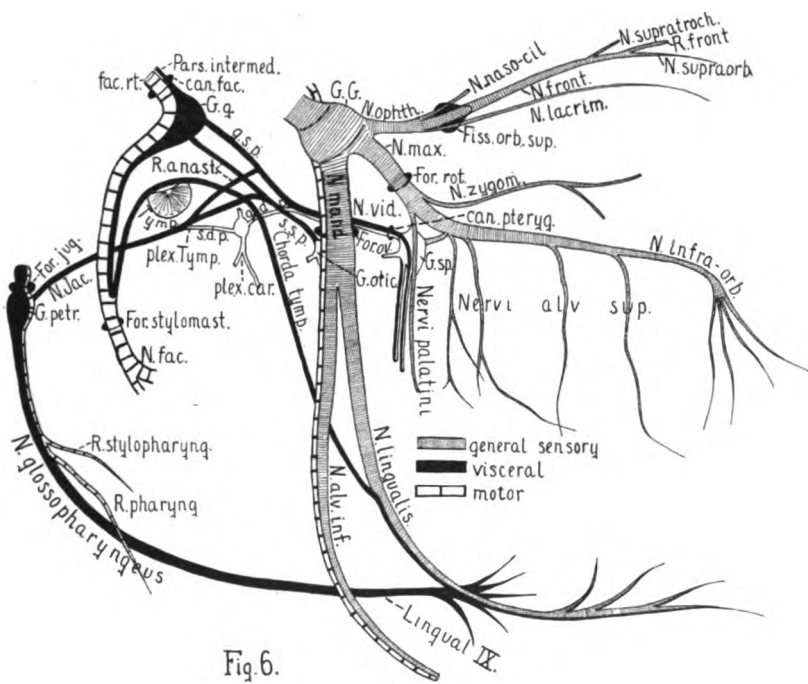


Fig. 5.

Diagram showing various courses advocated for the taste fibers in man. (Modified from Cushing.) The courses advocated in this article are shown by heavy black lines, other courses are indicated by dashes or dotted lines. Chorda tympani, chorda tympani; fac. rt., motor facial root; G. g., Gasserian ganglion; G. g., geniculate ganglion; G. otic, otic ganglion; G. petr., ganglion petrosum; G. sp., sphenopalatine ganglion; g. s. p., great superficial petrosal nerve; N. fac., facial proper; N. Jac., Jacobson's, or the tympanic nerve; N. glossopharyngeus, the lingual ramus of the IX; N. lingualis, the lingual V nerve; N. mand., mandibularis V. nerve; N. max., maxillaris V nerve; N. ophth., ophthalmicus V nerve; N. vid., vidian nerve; Pars intermedia, pars intermedia of Wrisberg, the sensory root of the facial; Rami anast., anastomotic rami between the geniculate ganglion and tympanic plexus and the small and great superficial petrosal nerves, respectively; s. s. p., small superficial petrosal nerve; Tymp., tympanum.

FIG. 6.

Diagram of the trigeminal, facial and glossopharyngeal nerves in man, from the right side. The glossopharyngeal nerve, instead of appearing in its normal position in front of the facial has been placed behind it. This is its true morphological position and such a change makes it more easy to compare this diagram with Figs. 1-4, of the lower vertebrates. This change necessitates the lengthening of Jacobson's nerve and a slight distortion of the tympanic plexus. The postganglionic sympathetic system is unshaded. It should be noted that the visceral nerves shown in black contain not only taste fibers but also several kinds of preganglionic sympathetic fibers of the efferent vaso-dilator and excito-glandular type. Many of these nerves undoubtedly contain also postganglionic fibers from the unshaded sympathetic ganglia. The general sensory fibers of the glossopharyngeal have not been indicated in the diagram. Can. fac., canalis facialis; can. pteryg., canalis pterygoideus; chorda tymp., chorda tympani; fac. rt., motor facial root; Fiss. orb. sup., fissura orbitalis superior; For. jug., foramen jugulare; For. ov., foramen ovale; For. rot., foramen rotundum; For. stylomast., foramen stylomastoideus; G. G., ganglion Gasseri; G. g., ganglion geniculi; G. otic., ganglion oticum; G. petr., ganglion petrosum; G. sp., ganglion sphenopalatinum; g. d. p., great deep petrosal, from the carotid plexus to the great superficial petrosal to form the Vidian nerve; g. s. p., great superficial petrosal, from the geniculate ganglion to the sphenopalatine ganglion, probably carrying taste fibers for the soft palate through the palatine nerves; N. alv. inf., nervus alveolaris inferior; Nervi alv. sup., nervi alveolares superiores; N. front., nervus frontalis; N. infra-orb., nervus infra-orbitalis; N. Jac., nerve of Jacobson or the tympanic nerve; N. lacrim., nervus lacrimalis; N. lingualis, nervus lingualis for the anterior part of the tongue; N. mand., nervus mandibularis V; N. max. nervus maxillaris V; N. naso-cil., nervus naso-ciliaris; N. ophth., nervus ophthalmicus V; Nervi palatini, palatine nerves for the soft palate; N. supraorb., nervus supraorbitalis; N. supratroch., nervus supratrochlearis; N. vid., vidian nerve; N. zygom., nervus zygomaticus; Pars intermed., pars intermedia of Wrisberg, the sensory root of the facial; plex. car., plexus caroticus; plex. tymp., plexus tympanicus; R. anast., anastomotic rami between the geniculate ganglion and tympanic plexus and the small and great superficial petrosal nerves, respectively; R. front., ramus frontalis; R. pharyng., rami of the glossopharyngeal nerve for the pharyngeal plexus; R. stylopharyng., ramus stylopharyngeus IX; s. d. p., small deep petrosal nerve from the carotid plexus to the tympanic plexus; s. s. p., small superficial petrosal, formed by the junction of the Jacobson's nerve through the tympanic plexus and the anastomotic branch from the geniculate ganglion; Tymp., tympanum.



A CONSTANT BURSA IN RELATION WITH THE BUNDLE
OF HIS; WITH STUDIES OF THE AURICULAR
CONNECTIONS OF THE BUNDLE.

BY

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WITH EIGHT FIGURES.

At the suggestion of Professor Dwight, I undertook an investigation of the anatomy of the auriculo-ventricular bundle of His. The amount of literature on the subject has reached a considerable size—beginning with the discovery by Kent (1), and also by His (2) in 1893, and growing with increasing interest to the present time. To give an adequate outline of the work which has been done by various authors would be a needless and time-consuming repetition of what is already in the literature, and this I wish to avoid as far as possible in this paper.

Perhaps no single structure in the human body has, of recent years, received more careful study and been the subject of more painstaking investigation than this one. Whether the function of the bundle of His is proved or not is not within the scope of this paper. It is sufficient to say that although the observations of anatomists, the ingenious experiments of physiologists, and the more crude ones of nature, observed by pathologists and clinicians, point convincingly to the accepted theory of its function—that of conducting the auricular impulse to the ventricle—yet they have by no means brought conclusive evidence to bear upon the subject. No one will dispute, however, that a sufficient number of facts have been brought to light to make this structure of vast interest. Of all the structures of the human body—with perhaps the exception of some brain tracts—it stands alone as one, the existence of which was asserted on other than anatomical grounds—in fact, in opposition to the universal opinion of anatomists. On *a priori* evidence, deduced from certain experiments of his own, Gaskell (3) in 1883 concluded that there must be

a muscular connection between the auricle and ventricle in the turtle's heart. He looked for, found, and described this connection. But it was not even then thought that the mammalian heart was similar in this respect. Kent, in 1893, discovered the muscular connection in the mammalian heart. Later in the same year, His discovered the auriculo-ventricular bundle in the human heart, and concluded that it was the sole muscular connection between the auricle and ventricle. The next notable advance in the anatomy of the bundle of His was the microscopic work of Tawara (4) and the discovery that the Purkinje fibres in the ventricle were terminal connections of the bundle and that it was distributed to all parts of the ventricles. It was partly these facts that caused Tawara to establish the fascinating theory that it was a conducting system alone, and not contracting. I have found no experimental evidence in the literature to support the theory that it is not a contracting muscle, and histological evidence does not exclude the possibility of its being a contracting as well as a conducting muscle, as others are. In an ox's heart, which was removed quickly after death of the animal and handed to me while still beating, on opening the right ventricle I could clearly see a ridge made by the right septal branch. The endocardium being moist it presented a shining surface and any disturbance in the reflected light could easily be noticed. I observed that there was a movement along this ridge and that this movement was simultaneous with the contraction of the auricle and that it preceded that of the ventricle, which was now very feeble and giving out. The movement was a peculiar trembling or shivering, not unlike the fibrillatory movements which I have seen Professor Porter produce in the ordinary cardiac muscle by ligaturing a branch of the left coronary artery in a dog's heart, and it existed for a short time after the ventricle had ceased to contract. Whether the movement advanced from the direction of the auricle toward the ventricle, I was unable to ascertain. This would have to be investigated by physiological experiments, which I was not prepared to make at the time.

Whether the system is contracting or not, or the accepted theory of conduction is a correct one, I was led to believe that there must be friction with the surrounding parts, or some provision for lessening

such friction. If the muscle contracts, it must contract before the ventricle; and if it merely stays stationary we should have the condition of a vigorously contracting muscle by the side of, and surrounding, a comparatively stationary one, and the resulting friction would still be great. This led me to look for some protective arrangement about the bundle.

The dissecting-room subject is not suitable for studying the bundle of His; for as a rule the natural color is lost and it is more difficult to follow in naked-eye dissections. The material used was fresh; and in order to get the best results, Professor Dwight, whose kindly assistance and valuable suggestions have helped me greatly in this study, arranged for me to be present at a number of autopsies to examine the heart immediately on removal. For this privilege I have also to thank Dr. Oscar Richardson, Assistant Pathologist to the Massachusetts General Hospital; Professor Mallory, Pathologist to the Boston City Hospital; and Medical Examiners McGrath and McDonald. The number of human hearts dissected was ninety-six. Besides these, twenty-three were used for microscopic work, and a number of sheep's and calves' hearts were used both for microscopic and gross work. I was unable to add anything to the histology of the auriculo-ventricular bundle, which is already well known. In all cases it was possible to dissect out the main bundle to its bifurcation. The right septal branch could be followed as far as the ridges of muscle which, in the human heart, represent the moderator band, but the left septal branch is broad, and so thin that it is usually taken off with the endocardium in the attempt to dissect it in the human heart; it can, however, be easily dissected in the sheep's or ox's heart.

I shall have to review briefly some of the anatomy of this region, for unless one is thoroughly acquainted with these parts it is most difficult to find the auriculo-ventricular bundle; but if certain variations are known, and it is remembered that the only constant landmark is the central fibrous body, there will be very little difficulty. It is, therefore, very important to be able to locate the central fibrous body, and to be aware of the other variations. If we look into the human heart from the right side, we cannot, as a rule, see the central fibrous body, but we can find it in one of the following ways: By

pulling on the Eustachian valve, we shall be able to see the origin of the fibrous band which runs along it under the endocardium; this origin is the upper left angle of the central fibrous body. If we place one finger in the left auricle and the thumb in the right, holding the interauricular septum between, and follow it up to its junction with the interventricular septum, we can thus locate it, for it is at the junction of these two septa. If the *pars membranacea septi* is large, we can locate the central fibrous body from the right side by holding the heart up to the light, and the central fibrous body will be in the upper left corner on the auricular side of the auriculo-ventricular fibrous band. Again, we can locate it from the left side by putting a pin through the origin of the mitral valve, near its junction with the *pars membranacea septi*. Lastly, sometimes we can feel it, but not often. If we insert a sharp knife at a point 2 mm. below and anterior to the central fibrous body we can cut down on the beginning of the main bundle as it enters the ventricular septum. The direction the main bundle takes is along the lower border of the *pars membranacea septi*, but this border is not constant, because very often the subaortic musculature comes up high, as shown in Fig. 5, and takes up the greater part of the *pars membranacea septi*; and in these cases we have certain displacements of the bundle. The direction will be the same, but it will be either buried deeply in the muscle or pushed so that one may see it under the endocardium in the left ventricle. In the latter case, if we wish to expose it from the right side, it will be necessary to cut deeply in the central fibrous body. Sometimes the bundle or its branch may be seen on the right side, showing through the endocardium, without any more dissection than removing the end of the septal cusp. It cannot be mistaken on account of its characteristic color and size. It is a narrow, whitish band, seldom more than two or three millimeters in width, and rarely so wide, and showing distinctly from the darker ventricular muscle. The bundle runs along for about two centimeters and then divides into right and left septal branches, usually at the lower angle of the *pars membranacea septi*. One of these branches—the right septal branch—runs along the septum almost superficially on the right side, and can be followed into the vestigial moderator band in the human heart. The left septal

branch can be seen as a broad thin layer of fibres through the endocardium on the left side. Fig. 2 is a drawing of a heart which shows the left septal branch as seen through the endocardium of a fresh human heart in a good subject. Tawara has shown that these branches (right and left septal) are distributed to all parts of the ventricles, the terminals being Purkinje fibres. From the point of incision above mentioned, the bundle can be traced back to the auricle, either through the central fibrous body or more superficially, and here it is said to be lost in a reticulum which is different histologically from other parts of the bundle and from other parts of the heart. This node can be dissected out as a definite structure—at least in the human and other mammalian hearts which have come under my observation—and I propose to show in this paper that it has definite connections with the musculature proceeding to the auricular appendages of both right and left auricle, and with the musculature around the fossa ovalis and the sinus venosus.

Keith was impressed with the distinct fibrous sheath which surrounds the bundle, isolating it from the ordinary cardiac muscle, and following the branches to their terminal ramifications (7). This isolation may be considered as an indication that the system is there for the simultaneous delivery of a single co-ordinated stimulus to all parts of the ventricles. The idea appeals to one, for there is a perfect network of fibres, and each branch carries its insulating (if one might so call it) fibrous tissue with it. It is separated from ordinary cardiac muscle cells until it has been thoroughly distributed. It was about this sheath that I looked for some protecting mechanism, and on examining it I found that it consists of two layers, more or less distinct, one around the muscle itself and the other on the wall of the muscle surrounding it. The space between is usually crossed by fine trabeculæ and is well moistened with a lubricating fluid, but in some parts there are no trabeculæ and only a space with the lubricating fluid. This is especially the case along the main bundle when the chordæ from the valves are inserted just over it, or when the bundle at its beginning disappears behind a nodule of muscle to get to the left side, as in Fig. 5. The fluid is of greater consistency than ordinary lymph and is somewhat tenacious in character. In the

fresh heart it gives the muscle a peculiar sheen, and causes it to slip easily from under a blunt instrument, as a pencil. This fluid is to be found throughout the branches as far as they can be dissected, as well as around the main bundle, where in one case it was so abundant that on opening the bursa with the point of a sharp knife it exuded in the form of a droplet. In hearts which showed atheromatous patches and thickened endocardium, I have sometimes found what I would consider an excess of this fluid, and in these cases it was more watery than usual. As a rule, the quantity is scanty and cannot be brought together to form a droplet. In two cases in which the hearts were about two days old, and had been in the freezing chamber for that time and were then thawed out, I located the bundle by seeing the fluid through the endocardium, and in it were bubbles of air which were made to move up and down the main bundle by pressing the tissue on either side. The fluid seemed more watery than it should be, and whether it filtered through or was the result of some pathological process, as bursitis, I was unable to determine. In other hearts which were subjected to the same process this did not occur.

There are several forms of this bursal space, ranging from very loose areolar tissue with lubricating fluid in the cellular spaces, which always connect with each other along the line of the bundle, to distinct cavities filled or lubricated with fluid, and no trabeculæ crossing the intervening space. In the usual form there are one or two large spaces or one continuous space with very fine trabeculæ crossing from the walls of the canal to the auriculo-ventricular muscle.

The size of the bursa depends on the size of the bundle of His, and the character depends upon the position of the surrounding structures. For example, if the insertion of the chordæ be over the course of bundle, in a line along the lower border of the *pars membranacea septi*, the character of the bursa will be open—that is, it will be a space crossed by few if any trabeculæ, and the lubricating fluid will be more in evidence, probably because this condition causes extra friction by the pull of the chordæ of the valves on the tissues over the bundle of His. Again, if the bundle be very small, it will not be easy to demonstrate the bursa, though in all cases its essential character can be made out by careful dissection. In hearts in which the

subaortic musculature comes up high, and when the main bundle lies deeply in the septum, it is not easy to demonstrate, but in this kind of septa, when the main bundle is to be dissected superficially on the left side as in Fig. 4, it can be seen under the endocardium of a healthy heart as a grayish translucent line, and fluid can occasionally be demonstrated without dissection by pressing both ends so that the bursal space bulges. In these cases also the bursa can be dissected from the right side before the bundle disappears behind the nodule of subaortic muscle, as in Fig. 5. The majority of cases are best demonstrated from the right side when the direction of the main bundle is such that it runs along the lower border of the pars membranacea septi and the chordæ of the cusps are inserted into the edge just over the main bundle. If we have a large main bundle under these conditions and make a small opening with the point of a sharp knife at this position, by lifting up the edges with the forceps, or raising the edges with threads, as shown in Fig. 3, we can easily see a dark cavity and the main bundle of His lying in it. We can now insert a blowpipe, and blow up the space to see the extent of the bursa. As a rule, such cases can be blown up as far as the reticulum, and in rare cases even beyond that into the loose tissue about the coronary sinus and the auriculo-ventricular groove. When the mouth of the blowpipe is inserted into the lower part, the right septal branch can be blown up for a distance more than half-way down the vestigial moderator band along the course of the right septal branch. If we now turn to the left ventricle, we shall probably find bubbles of air under the endocardium, showing that it has followed the branches under the endocardium of the left ventricle, and that the spaces in the loose tissue here are continuous with those of the right side. The use of the blowpipe, however, is not always successful on account of the difficulty of correctly inserting the end into the space and thus preventing the escape of air from it.

In the sheep's and calf's heart the bursa is always crossed by trabeculæ, but it can be blown up with very slight pressure, showing continuity of the space. In the ox's heart there is a large bursa, about a centimeter in area, between the central cartilage and the bundle of His; and this connects with the spaces along the course of

the main bundle. It is obvious that such a provision is necessary here for protection against the impact of the cartilage. On account of the larger auriculo-ventricular bundle in the sheep's and ox's heart, one might expect to find a more marked bursal space along its main trunk and branches, but since it lies deeply in the muscle it is not subjected to the pull of chordæ and consequently we have, as it were, a partially developed bursa along its course, with numerous trabeculæ and with the lubricated surface.

The purpose of the bursa is undoubtedly to lubricate and protect the bundle of His from the friction of the surrounding cardiac muscle as it contracts. It is so striking in the gross dissections that it is surprising that it has not been observed before, and this can only be explained by the fact that most of the study done on the subject has been done on microscopic sections and in these it is likely to be overlooked. Careful dissection reveals it best.

AURICULAR CONNECTIONS.

A great deal of work has been done on the ventricular connections of the bundle of His, but little information is to be found concerning the auricular side. Strangely enough the writers seemed to be content with the statement that it has its roots in the annular and septal fibres of the right auricle. This is the most I have been able to find in the literature concerning the auricular connections.

In my dissections I tried to trace the system to its ultimate ending in the auricles by following the main bundle through the central fibrous body or cartilage, keeping on the surface of it until I could dissect no further without cutting small strands of muscular tissue, which comes from the meshwork from which the bundle has been described to arise, and which Keith calls the reticulum. In the first dissections, sheep's and calves' hearts were used. As the bundle is followed up in this way, we find that we have removed the superficial layer of auricular muscle and that the fine strands mentioned above are proceeding from the reticulum to the superficial musculature of the auricle, and that they are the only connections it has with this superficial layer, the fibres of which are at right angles to the bundle of His. Therefore the bundle of His is not a continuation of this layer.

The reticulum begins on the auricular side of the central cartilage, where it spreads out immediately, having an area of about a square centimeter. It is similar in color to the auriculo-ventricular bundle and is not so hard as the ordinary auricular or ventricular muscle. In my dissections it is flat and has a surprisingly uniform shape, somewhat like that of a nerve ganglion. It has a very thin capsule of connective tissue, which is a continuation of the sheath surrounding the bundle, but it is thinner and more delicate. If, in dissection, we get away from this sheath, which is the natural line of cleavage, it will be impossible to reveal the reticulum as a definite structure; but if we dissect carefully, not having the specimen too wet, and follow the sheath, a dissection can be made similar to the plates shown. (Figs. 6 and 8.) When the reticulum is dissected out, as in Figs. 6 and 8, we find that there are several well-marked roots or branches which can be traced for a short distance into the auricles, as well as many more minute twigs not shown—all arising in this reticular mass. As these branches leave the reticulum they are distinctly pale in color like the other part of the system, but they gradually merge, in character and color, into the ordinary auricular musculature. Each part of both auricles would seem to be connected with the reticulum through these muscular bands and through smaller twigs. The largest three are shown in the drawing of the dissection of the sheep's heart, Fig. 8, and in the photograph of the dissection of the calf's heart, Fig. 6. The small twigs which went to the surrounding muscle close by have been dissected away, leaving three large auricular connections and the main auriculo-ventricular bundle going to the ventricles, and also a well-marked bundle which enters and disappears into the ventricular muscle, and into the septal cusp, just before the main bundle leaves the auricle through the central fibrous cartilage. Some of the fibres of this branch end in the septal cusp, as has been mentioned by other writers, and some pass through, under the cusp, into the mass of septal muscle which arises from the central fibrous body. These fibres have not, I believe, been described before, excepting that they may be the second muscular connection casually mentioned by Kent (5). He speaks of a spindle-celled muscular continuity of the auricle and

ventricle, to be found in the auriculo-ventricular fibrous ring, as well as the connection now known as the bundle of His, but this has not been confirmed by other investigators. Doubtless the function of these fibres is to supply the posterior part of the septum and the adjacent ventricular muscle. It is indeed what one would expect to find, seeing that there is no backward turning branch from the main bundle of His which would supply a large part of the posterior musculature. It is well marked and easily dissected in the sheep's and calves' hearts, and can, with somewhat more careful dissection, be made out in the human heart. I have no doubt it is always present, even if at times it is obscure. I shall refer to it in this paper as the accessory septal branch of the reticulum. The existence of such a branch would probably explain the experiments of Paukel (6), in which he ligatured the main bundle and still had no incoördination in the beats of auricle with ventricle. This connection may have escaped the ligature and carried the coördinating impulse to the ventricle.

The auricular connections of the reticulum in the sheep's and calves' hearts consist chiefly of three large bands radiating from it, viz.: (1) a branch to the interauricular septum and proceeding almost as far as the superior cava, where it is lost in the auricular musculature; (2) a branch, as shown in Figs. 6 and 8, which can be traced to the pericardial surface of the right auricle, blending with the auricular muscle as it proceeds on its way to the pectinate muscles of the right auricular appendix; (3) a similar branch going to the left auricle, which can be seen as in Fig. 8 when the coronary sinus is removed, or as in Fig. 6, where it is shown giving some branches to the coronary sinus. Besides these there are numerous smaller branches radiating from the reticulum to adjacent auricular muscle. These are fine threads of muscle, and can be well seen in the human heart, in which the above-mentioned main branches are not so well marked. Fig. 1 gives a diagrammatic representation of the radiations in the human heart. The smaller radiations are also of a paler kind than the ordinary auricular musculature. The auricular connections are not so easily dissected as the ventricular bundles, owing to there being no bursal space; and the sheath, if at all existing

distal to the reticulum, is not so marked. But the color of the muscle helps us greatly in the dissection, and when we are familiar with its relationship we cannot but be impressed with its morphological difference from the rest of the auricular muscle. This difference has been pointed out in the ventricular portions, where it is very striking; but the auricular connections are quite as striking in color and arrangement. In the first place, the reticulum has the naked eye appearance of a nerve ganglion, and streaming from it, or to it, are certain well-defined bundles of muscle. For descriptive purposes in this paper, I have called these bundles branches of the reticulum. If the reticulum were a fixed body, as a cartilage or the fibrous ring, we might be inclined to call it the insertion of these bands, but it is quite movable—more so than any other part of the auricular muscle. It has no fixed attachment to the central fibrous body or cartilage, or to the annular fibrous ring. Therefore we cannot consider it as an insertion of a muscle in the ordinary sense. In the sheep's and in some human hearts it would seem that a pull on the reticulum would be transferred to the main bundle of His, and thence down along its branches. This would be purposeless, so far as auricular efficiency is concerned. The chief function of muscle is contractility, and any other function or quality is subservient to this. It is usual, however, for any muscle to have two attachments, or to be arranged in a circular form in order to gain any advantage of contraction. Here we have a muscle which has practically no attachment at one end. It has been suggested that the system is conductive only, and this would coincide well with anatomical findings.

The auricular parts of the system—that is, the reticulum and branches, first lie between the auricles as they turn in to form the interauricular septum and to join the ventricular septum at the central fibrous body or cartilage. If we wish to show the reticulum from either auricle, we must cut through the septal muscular wall belonging to that auricle from the inside of the heart, and we shall find it (the reticulum) lying against the septal muscular wall of the other auricle. It is thus held in between the two auricles as between two leaves of a book. If we trace the auricular septal branch, we find

that for a short distance—two or three centimeters—it still lies between the auricles, distributing itself as it proceeds along the interauricular septum, and giving a large branch to the sinus venosus. Its terminals become intimately mixed with the auricular musculature. The other branches, as has been previously pointed out, come to the pericardial surfaces (immediately under which they lie, especially in the right auricle) as they proceed to the auricular appendages. We thus have well defined branches coming from or going to the reticulum from the great system of muscles in the auricles, viz.: the interauricular septum and the two auricular appendages. If this is a conducting system at all, it is clear from the anatomy of the structure that the auricular impulse must begin in the reticulum and radiate to the auricles through the auricular branches, or that it begins simultaneously in both auricles and is carried through its branches to the reticulum. If this is the case, it is within the bounds of possibility that the left auricular branches control the left ventricle, that the right branches control the right ventricle, and that their meeting at the reticulum and continuing in one main bundle to the ventricles is only an economy of space. If it is not a conducting system, how can we explain its existence? It must be admitted that it is admirably suited for conducting mechanism, and very poorly fitted for mechanical purposes. If it were a contracting system also, we would expect to find an increase in size in hypertrophied hearts. Keith (7) and Tawara (4) have noted that there is no such increase in size nor any diminution in atrophy; but with such a small structure as this I do not think it possible for any one to say with certainty that there is, or is not, this change, since the size of the muscle cell varies even in normal hearts, and there are no means of knowing what size the muscle or its cell structure were originally. From the series of hearts which I examined I was unable to come to any such conclusion. Some of the hypertrophied hearts had large bundles. The largest bundle which I found in the human heart was in a hypertrophied heart in a case of pernicious anæmia. It was 3.5 mm. in width throughout the whole course of the main bundle.¹ The next largest is shown in Fig. 1, which was from another

¹This specimen and the others from which the accompanying figures were taken are now in the Warren Museum, Harvard Medical School.

case of pernicious anæmia. On the other hand, most of the hypertrophied hearts showed bundles which were unusually small. This may of course be due to pressure atrophy, and what was originally large may have been thus reduced in size as the hypertrophy went on. In this connection also the blood supply must be an important factor. It has recently been suggested by Mönkeberg (8) that the conducting system has a blood supply unconnected with that of the surrounding muscle. He based his belief on pathological findings. Before I read his excellent paper I had been working on the blood supply and had come to the same conclusion; but I am not quite sure that the bursa also may not have something to do with nutrition of the bundle. This work is not yet completed, but I am able to state definitely that the auriculo-ventricular bundle has a special artery which, in the human heart, arises from the right coronary, and in the sheep's and calf's heart it is a branch of the left coronary. It enters the bundle at its beginning and follows it in direction. Not only has the bundle a special artery, but it also has special veins which follow the bundle and empty into the right (and probably left) auricle through the Thebesian openings.

SUMMARY.

The important new facts and considerations brought out in this study are the following:

1. There is a constant bursa or lubricating mechanism in relation with the auriculo-ventricular bundle, in view of which the possibility of bursitis must be considered in connection with certain temporary cardiac symptoms, and with conditions met with in acute febrile diseases, such as acute rheumatism, endocarditis, etc.
2. The bursa is capable of facilitating the extension of any endocardial process on account of its anatomical relationship with the endocardium, and of the fact that even small twigs of the auriculo-ventricular bundle which lie immediately under the endocardium are surrounded with cellular tissue, the spaces of which are continuous with the main bursa.
3. The existence of the bursa proves that either the auriculo-ventricular bundle does not contract at all, or that it contracts in a

different way and at a different time from the contraction of the ventricle. The observation made on the ox's heart, mentioned in the foregoing pages, supports the latter view.

4. There is a striking gross resemblance of the reticulum in the calves' and sheep's hearts to a nerve ganglion, when dissected out as shown in Figs. 6 and 8; and its connection with all parts of both auricles is through three large trunks and a number of smaller twigs, and not, as was once thought, merely arising in the right auricle only. These connections point to the possibility of the contraction wave either beginning in the reticulum and proceeding through its branches to all parts of both auricles, or to its coming from all parts of both auricles to meet at the reticulum. In this case there would be a probability of each auricle controlling the time of contraction of the corresponding ventricle, and the meeting at the reticulum of the various bundles of fibres from both auricles and proceeding thence to the ventricles as the auriculo-ventricular bundle, would merely mean an economy of space.

5. The accessory ventricular branch of the reticulum must be counted on in physiological experiments.

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FIG. 1.—This is a drawing of a human heart opened from the right side, showing the right auricle and the right ventricular surface of the interventricular septum. The great vessels are somewhat diagrammatic, as they were not saved in a suitable state for a clear drawing. The auriculo-ventricular bundle is large—being 3 mm. in width all along its course from the central fibrous body to its bifurcation. The central fibrous body is represented in black just to the left of the index line to the main bundle and on the auricular side. The auricular fibres of the system are shown streaming from the superior cava, the annular muscle around the fossa ovalis, the right auricular ring and the cusps. The septal artery, which gives small twigs to the reticulum and to the bundle, is also shown. The bundle is dissected at the point of bifurcation, to show the beginning of the left septal branch. The right septal branch is dissected as far as possible into the moderator band. The index lines explain sufficiently well the other landmarks in the dissection.

FIG. 2.—This is a drawing of a human heart opened from the left side to show the left septal branch of the auriculo-ventricular bundle streaming down the interventricular septum. In this case no attempt was made to dissect it out, because it showed clearly as represented through the normal endocardium. It is always quite superficial on this side, although in a thickened endocardium it cannot usually be seen so well in the human heart. The spaces under the endocardium here can be blown up from the bursa of the main bundle. Notice the relationships of the non-coronary cusp, pars membranacea septi, and the base of the mitral valve to the course of the fibres of the auriculo-ventricular system.

E. J. CURRAN.

Main Bundle of His

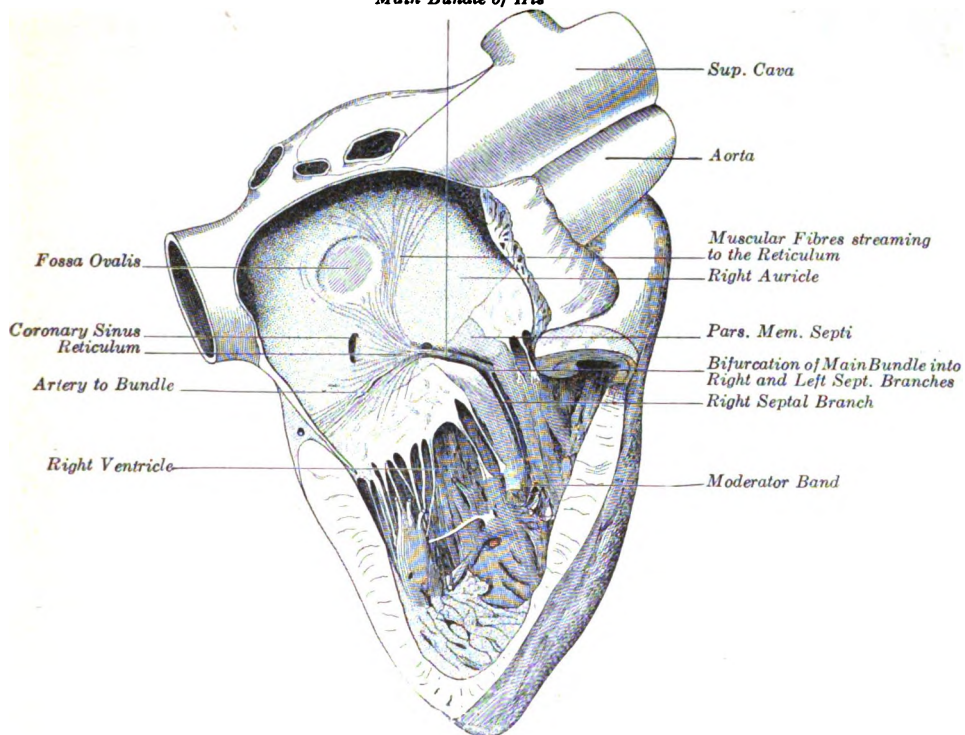


FIG. 1.

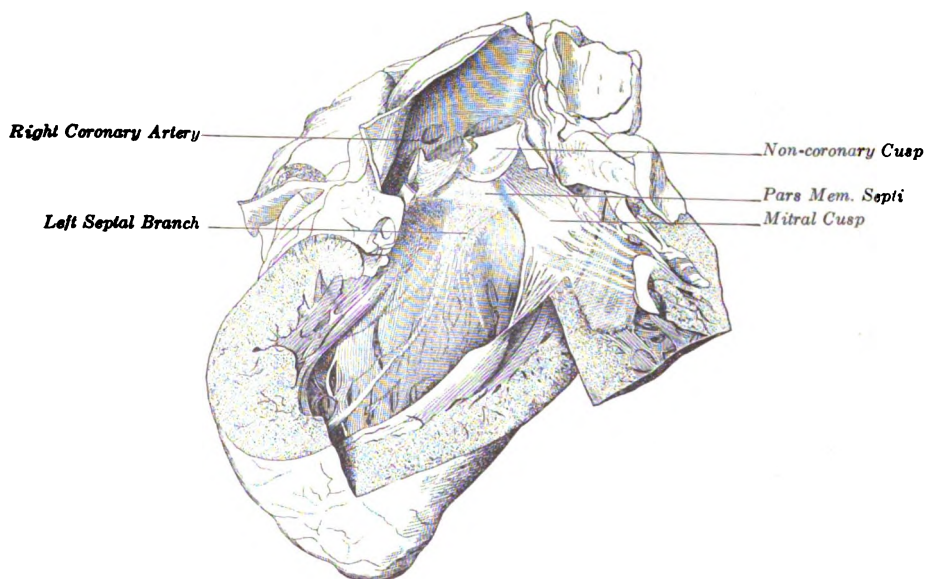


FIG. 2.

FIG. 3.—This is a drawing of the region around the auriculo-ventricular bundle as seen from the right side. *F* is position of central fibrous body where the main bundle begins to leave the auricle. *H*, fossa ovalis. *G*, coronary sinus. *C*, auricular appendix. *E*, a cut through endocardium, over the main bundle, showing the latter lying in the bursal groove or canal, and the bursal space emphasized by a pull on the threads *A* and *B* which are put through the endocardium for this purpose. *D*, a hollow ridge along the course of the main bundle, caused by the pull on the thread *B*.

FIG. 4.—Fig. 4 is a drawing of the subaortic region in the left ventricle, showing the bursa on this side. This is a common variation from the normal, and it occurs when the subaortic musculature comes up high, invading the pars membranacea septi. It is the left side of the heart from which Fig. 5 was drawn. The subaortic musculature, as drawn in Fig. 4, shows some of the various directions which the fibres of this may take. In this dissection the left septal branch first appears below the transverse fibres, about the end of the index line marked "Left Ventricle," but they have lost their color and do not show in the drawing. The bursal space is held out by a thread inserted for the purpose, and the main bundle is seen lying at the bottom of it.

FIG. 5.—This is a part of the right auricle and the interventricular septum, as seen from the right ventricle of the heart from which Fig. 4 is drawn. Here a nodule of muscle grows up from the interventricular septum and invades the pars membranacea septi, making it very narrow. From the reticulum the main bundle can be seen for 3 or 4 mm. and it disappears between the central fibrous body and the septal muscle. At this point there is a well-marked bursa which does not show well in the drawing. The main bundle divides on the other side of the septum and the right septal branch, as indicated by the index line, appears on the right side, just after the division. It could be seen distinctly through the endocardium, but in the dissection this has been removed. The right septal branch then disappears into the papillary muscle, which is sometimes continuous with the moderator band. Other points in the drawing are explained by the index lines.

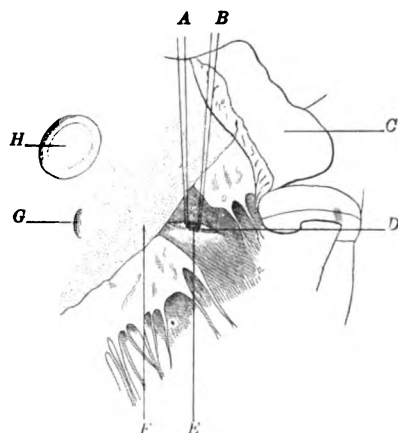


FIG. 3.

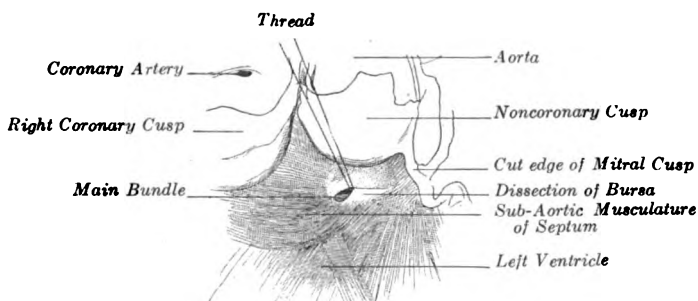


FIG. 4.

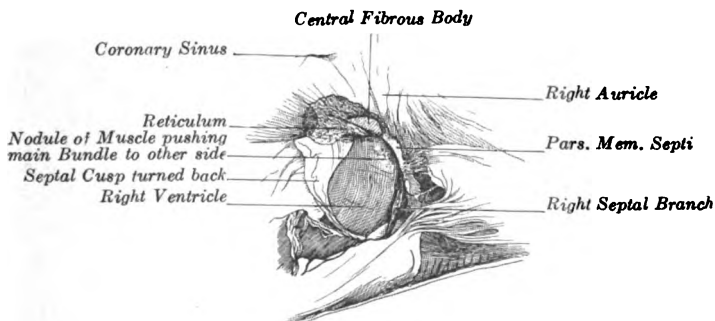


FIG. 5.

FIG. 6.—Fig. 6 is from a photograph of a dissection of the reticulum with its chief auricular branches and the auriculo-ventricular bundle as seen from the right side of a calf's heart. The external walls of the right auricle and ventricle are removed. The septum in the region of the reticulum is made up of the septal wall of the right auricle lying against the septal wall of the left auricle, holding between them—as between two leaves of a book—the reticulum and the beginning of its branches. In order to see these, the right auricular part of the septal wall must be removed, as shown in the photograph, and on careful dissection the reticulum will appear as a mass somewhat resembling a ganglion in form. The right auricle is cut away sufficiently to show the branch going to the left auricle with its distribution to the coronary sinus, under which its course lies as it proceeds in the direction of the auricular appendix and mouths of the pulmonary veins. The large branch which goes to the right auricular appendix is pinned down to the cut edge of the right ventricular wall. The trunk of the branches to the interauricular septum and the superior cava is dissected out for a short distance, sufficient to show its direction. Fibres going into the septal cusp and right ventricle immediately before the auriculo-ventricular bundle is given off, are also well shown in the photograph. Behind this pinkish pale mass (the reticulum and its branches) can be seen the darker muscle of the left auricle, some strands of which are inserted into the auriculo-ventricular fibrous ring and some into the central cartilage. A well-marked band of dark auricular muscle arising partly from the annular ring of the inferior cava, and also from the left auricle, can be seen disappearing between the fossa ovalis and the left auricular branch of the reticulum, under the septal branch, and again appearing in the small triangular area, as it is inserted into the central cartilage of the heart. These and other points are indicated in Fig. 7, which is a key to this photograph.

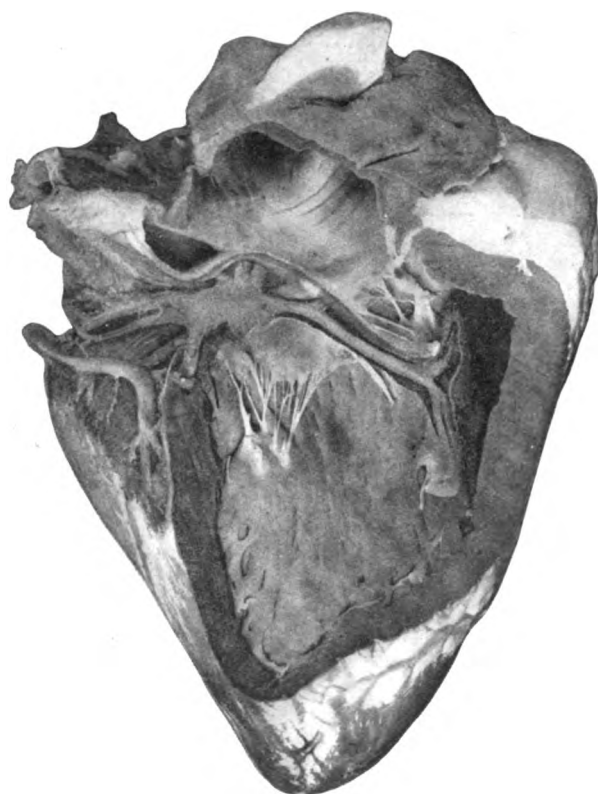


FIG. 6.

FIG. 7.—Key to Fig. 6. *A*, inferior cava turned up. *B*, septal branch of left coronary artery, which sends twigs to the reticulum and the auriculo-ventricular bundle. *C*, reticulum. *D*, fibres from the reticulum to ventricle and septal cusp. *E*, insertion of muscular band *H*, arising from left auricle and inferior cava. *F*, superior cava. *G*, Fossa ovalis. *I*, left auricular branch of reticulum going to mouths of pulmonary veins, auricular appendix, and coronary sinus. *J*, coronary sinus. *K*, branch of reticulum going to right auricular appendix, now pinned to the cut wall of the right ventricle. *L*, left ventricle. *M*, right auricle. *N*, branch from the reticulum to the inter-auricular septum and mouth of superior cava. *O*, central fibrous cartilage. *P*, a twig of right septal branch to conus arteriosus of right ventricle, given off before the remaining part enters the moderator band. *Q*, interventricular septum seen from right ventricle.

FIG. 8.—Fig. 8 is a drawing of a dissection of a sheep's heart, showing a view of the auricular connections of the auriculo-ventricular bundle similar to that shown by the photograph (Fig. 6). In this case the coronary sinus is dissected away and the left auricular branch, *E*, of the reticulum is shown at first as a wide band which, when it proceeds but a little distance, buries itself deeply in the left auricular musculature, only a fine strand of it showing on the surface for any considerable distance. *A*, trunk of left pulmonary veins. *B*, trunk of right pulmonary veins. *C*, left auricular appendix. *D*, fossa ovalis. *E*, left auricular branch of reticulum. *F*, septal branch of reticulum. *G*, reticulum. *H*, right auricular branch of the reticulum on its way to the auricular appendix. *I*, cut edge of the left ventricle. *J*, left ventricle. *K*, main auriculo-ventricular bundle. *L*, superior cava. *M*, right auricular appendix. *N*, right auricle. *O*, bifurcation of main bundle. *P*, right septal branch. *Q*, moderator band cut. *R*, right ventricle, septal wall. The accessory ventricular branch is also seen well in this direction.

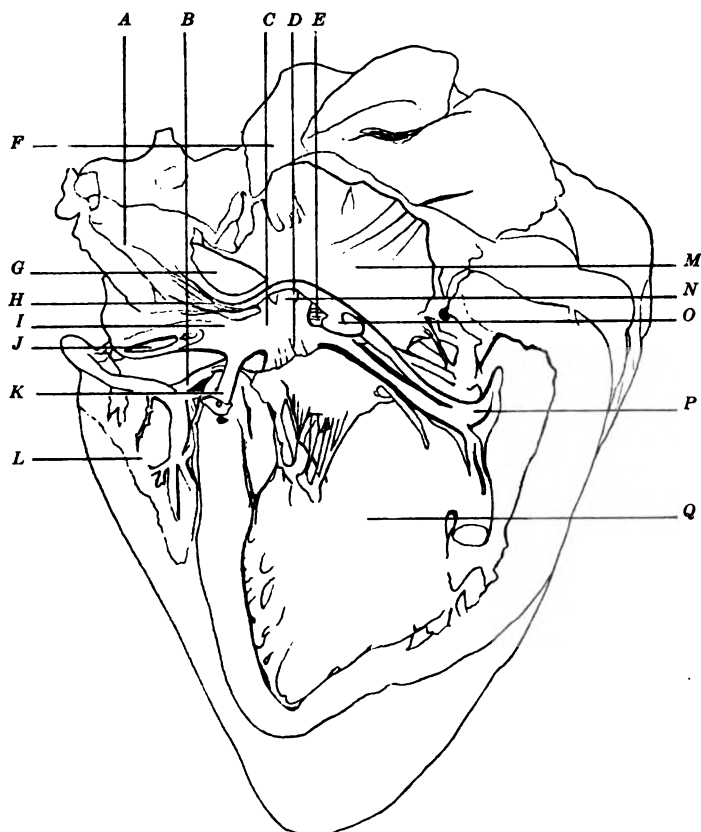


FIG. 7.

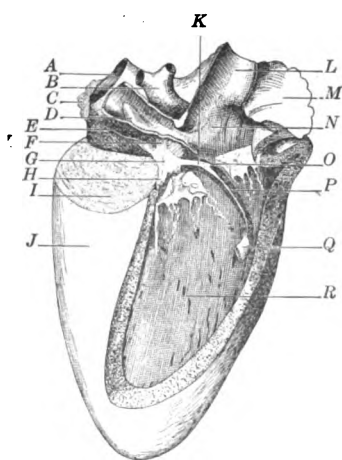


FIG. 8.

THE EFFECT OF CONTRACTION ON THE VOLUME OF THE SMOOTH MUSCLE NUCLEUS.

BY

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In a recent paper (American Journal of Anatomy, Vol. IX, No. 4, 1909) I have described the histological changes which occur in the smooth muscle nucleus during the contraction of the tissue. Briefly these changes are as follows: The nucleus decreases markedly in length and increases in thickness. The chromatin, which is distributed uniformly through the resting nucleus in a fine reticulum, as the nucleus shortens streams towards the poles, and there forms into coarse, deeply-staining strands. The nucleus thus appears to take an active part in the process of contraction.

By most authors, contraction in smooth muscle has been assumed to be due to an increase in the volume of the myofibrillæ brought about by the absorption of water from the interfibrillar substance. The observations reported in the present paper were made to determine whether there is any change in the volume of the smooth muscle nucleus during contraction, accompanying the marked changes in structure described in the preceding paragraph.

The material chosen was the intestinal muscle of *Necturus*. Here the nuclei are very large, in extreme extension reaching a length of eighty micra. They are large enough for fairly accurate reconstruction. Pieces of the muscle were fixed in Zenker's fluid, embedded in paraffin and cut serially. Some of the series were cut at four micra, others at five micra in thickness. The sections were stained either by Delafield's hæmatoxylin or in Heidenhain's iron hæmatoxylin.

Measurements of the volumes of a large number of nuclei, both from contracted and expanded muscle, were made. Two methods were used in determining the volume. The first method is as fol-

lows: In a given area of a longitudinal section of smooth muscle, the nuclei showing the greatest size were taken as nuclei cut in median longitudinal section. These were projected and drawn by means of a camera lucida at a magnification of 1200 diameters. Assuming that the nuclei were round in cross section, the volume was calculated. This was done by breaking each nucleus up into several frustra of cones, finding the volume of each and adding the several volumes. The following table is from a series of nuclei taken as representatives from a large number of measurements. In this table the magnified size has been reduced to the actual size. The length and width of the nucleus give a fair index of the amount of contraction. The first of the series therefore represents a nucleus fully contracted, the last is fully extended.

No.	Length in Micra.	Width in Micra.	Volume in Cubic Micra.
1	28	18	2786.74
2	30	17	2447.65
3	35	15	2938.52
4	43	9	1763.30
5	55	9	1940.82
6	62	9	2537.64
7	70	7	2013.68
8	72	7	2024.72
9	76	7	2031.12
10	82	5	1766.24

In the expanded muscle the nuclei are almost round in cross section, but in contracted muscle they are often considerably flattened. This probably accounts for the apparently slightly smaller volume in the expanded muscle nucleus shown in the above table. Therefore, as a check on this first series of measurements by (probably) a more accurate method, the volumes of another series of nuclei were found by reconstruction. The size of the nucleus made it easy to do this. Thin serial sections in cross section of the muscle fibres were made from both contracted and expanded muscle.

Definite areas in series from these sections were projected and drawn by aid of the camera lucida at a magnification of 1500 diameters. In these series the nuclei were easily traced throughout their entire length. From the serial drawings the volumes of the nuclei were found either by means of a planimeter or by reconstruction by Born's wax plate method (the volume in the latter case being measured by water displacement). The following table gives a few representative volumes taken from a large number of measurements by the planimeter method. As in the preceding table, the magnified size has been reduced to the actual size.

Number.	Length in Micra.	Volume in Cubic Micra.
1	27	2370.00
2	32	2400.00
3	37	2411.90
4	43	2240.00
5	47	2370.00
6	47	2434.00
7	53	2340.00
8	64	2472.00
9	70	2112.00
10	77	2408.00

The wax models of the nuclei showed very similar volumes, so a table is not given.

The above table shows little difference between the volumes of the resting and of the contracted smooth muscle nucleus. From the data it seems probable that during the contraction of the smooth muscle nucleus of *Necturus* there is no change in volume.

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A NOTE ON ORANGE G COUNTER-STAINING SUGGESTING A USEFUL METHOD IN THE MAN- AGEMENT OF EMBRYONIC TISSUE.

BY

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The general value of Orange G as a means of obtaining brilliant differentiation in counter-staining is too well known to require comment. The stain, however, appears to be ill adapted to many tissues, regardless of fixation and also without reference to the length of time the tissue has been in preservation.

Finding it difficult to get a good Orange G stain in several varieties of embryonic tissues, severally fixed in Merkel's, Müller's, Flemming's or Zenker's fluids, it was determined to use the stain experimentally with the view of finding some method by which the obstacle might be overcome. The first tissue experimented upon was a *Tragul*us embryo of 20 mm. which had been preserved in 85 per cent alcohol for five years. Having tried Orange G as a counter-stain to Delafield's hæmatoxylin in the usual manner without success, picric acid, eosin and acid picro-fuchsin were employed but failed to yield results.

Subsequently, by a reversal of the ordinary Orange G method and the introduction of an alkaline solution of the stain a decisive differentiation was obtained. A number of other tissues which were difficult as far as counter-staining was concerned have yielded entirely satisfactory results by this method; it is now used as the routine procedure with all embryonic tissues in this laboratory and has proved the most uniformly reliable means of securing an even and clear differentiation. The solutions needed for this stain are:

1. 1 per cent solution of Orange G in 60 per cent alcohol acidulated by .25 cc. concentrated HCl. to the 100 cc.

2. 1 per cent solution of Orange G in 60 per cent alcohol alkalized by saturation with lithium carbonate.

3. Hæmatoxylin solution (Delafield) full strength.

The following steps should be carefully observed:

I. Acid Orange G from 10 seconds to 1 minute.

II. Wash in 60 per cent alcohol.

III. Hæmatoxylin solution about 5 minutes.

IV. Wash in water.

V. Acid Orange G, about 1 minute.

VI. Wash in 60 per cent alcohol.

VII. Alkaline Orange G solution about 2 minutes.

VIII. Ascending alcohol series.

IX. Xylol.

X. Mount in Canada balsam.

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BOOK REVIEWS.

DIE MUSKELN DES MENSCHLICHEN ARMES. By Dr. Fritz Frohse and Dr. Max Fränkel. With 414 pages and 154 illustrations, part in colors, forming the fifteenth section of the "Handbuch der Anatomie des Menschen," edited by Prof. Karl von Bardeleben. Gustav Fischer, Jena, 1908.

This section of von Bardeleben's Handbook of Anatomy represents the result of an immense amount of detailed study by Dr. Fritz Frohse, of Berlin. The excellent illustrations for the most part are original, and nearly all have been drawn by Dr. Frohse and his brother, the artist, Franz Frohse. Dr. M. Fränkel, surgical assistant for many years of Dr. E. von Bergmann, at the surgical clinic at Berlin, has had chiefly to do with the surgical bearings of the subject.

The book begins with a sub-section devoted to general aspects, under which the external form is first treated, numerous good pictures being given to illustrate the relations of the surface anatomy to the underlying muscles. This is followed by a brief description from Kollmann of the plastic anatomy of the arm and by a few paragraphs devoted to a classification of the muscles of the arm, which the authors state are readily divisible into four groups; those of the shoulder, upper arm, fore-arm, and hand. The muscles of these groups are treated as in part superficial and part deep. A brief classification of the muscles according to action on the joints is also given and the nerve supply is briefly summarized.

There next follows a sub-section devoted to special anatomy, in which there is given an extensive description of the structure, relations, action, practical aspects and innervation of each of the muscles of the arm. References are also made to the length of the muscle-bundle components, to the segmental relations of muscle innervation and to muscle variations. The illustrations in this sub-section which show the distribution of nerves within the muscles form a welcome addition to descriptive human anatomy.

Following the descriptive anatomy of the individual muscles of the upper extremity there is a supplemental sub-section devoted: (1) to the muscle fasciæ of the upper extremity; (2) to the tendon sheaths and synovial bursæ of the hand; (3) to the length of the muscles including their tendons; (4) to the length of the muscle-bundle components of the various muscles; (5) to the weights of the various muscles; (6) to the origins and insertions of the muscles on the bones of the upper extremity; (7) to muscle variations; (8) to neurological aspects, including relations of innervation to spinal segments, the piercing of muscle by the nerves, the double innervation of arm muscles, and electrical stimulation. Each of these sub-divisions of the supplementary sub-section contains numerous new details of value.

The sub-section on the muscle fasciæ contains much of value but is less happily illustrated than most other subjects treated by the authors. We need good pictures of fasciæ and fascial compartments. The authors have missed an opportunity to supply this need. The sub-sections on the length of muscles with their tendons and on muscle bundles contain numerous important details and are well illustrated. In the sub-section on the weight of muscles there is set forth an extensive study of the weight of the muscles of the right and left arms of a muscular man and of a woman with weak muscles. In the sub-section on the muscle attachments to the bones of the arm excellent illustrations are given not only of the muscle attachments but also of sub-muscular bursæ. The attachments to the clavicle, scapula and humerus are illustrated on isolated bones; those to the radius and ulna are shown with these bones side by side in the position of supination; those to the bones of the wrist and hand with these bones in approximately their normal relations. Illustrations showing muscle attachments to the articulated skeleton of the entire upper extremity would add to the value of this sub-section. In the neurological sub-section but little space is devoted to the relations of the muscle-nerves to the spinal segments since the authors were unable through dissection to get accurate data of their own on the subject. In the sub-section on electrical stimulation the authors follow closely the descriptions of Toby Cohn "*Leitfaden der Elektrodiagnostik und Electrotherapie*," the material for which was prepared by Dr. Cohn in co-operation with the anatomical studies of Frohse and Fränkel.

Taking the book as a whole the anatomist will find in it many details of considerable value, but he will find comparatively few new and broad deductions drawn from these details. There is an almost entire absence of reference to embryology and comparative anatomy, the two great fields which serve to give unity and simplicity to morphology. The volume represents, however, a sincere contribution of patient labor and some real additions to descriptive human anatomy.

Charles R. Bardeen.

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NOTES.

THE RETIREMENT OF DR. HORACE JAYNE.

It is a matter of deep regret to the anatomists in this country that Doctor Horace Jayne finds it necessary to give up his active work as the head of the department of publications of the Wistar Institute. The editors of the journals for which he has worked so successfully and also his colleagues in the Wistar Institute wish to express their very keen appreciation of his untiring work and of his great generosity, both of which have made possible the bringing together the publication of the five principal anatomical and zoological journals of this country. The spirit of co-operation on the part of the Wistar Institute with the editorial boards of the various journals has led to a central publication office which has definite aims along certain lines. These lines are to simplify the machinery of publication, to raise the standard of book making, to stimulate the publishing of scientific articles in our own journals, and to increase the support of our journals both at home and abroad. It is along these lines, involving the task of co-ordinating the activities of some thirty-eight different editors of the various journals, that Doctor Jayne has worked for the past two years. The anatomists wish to express their gratification that the work so well begun is to go on through the continued co-operation of the Wistar Institute.

At the University of California, Professor Robert O. Moody, M.D., has been made acting head of the department of anatomy for the coming year.

Dr. Joseph H. Hathaway, A.M., M.D., formerly instructor in anatomy in the Cornell University Medical College, has been appointed professor of anatomy in the University of Louisville, Louisville, Ky. In the reorganization of the department microscopic anatomy and embryology are included in the chair of anatomy.

Dr. Wesley M. Baldwin, who has been instructor in anatomy in the Cornell University Medical College at Ithaca, has been appointed instructor in the same institution in New York City.

Dr. Henry McE. Knowler, Ph.D., formerly associate in anatomy in the Johns Hopkins University, has been appointed lecturer in anatomy in the University of Toronto.

In the recent reorganization of the medical faculty of the University of Pittsburgh, Dr. Benson A. Cohoe has been appointed professor and head of the department of anatomy. The department includes gross anatomy, histology, embryology and neurology. Dr. Cohoe was formerly associated with the anatomical laboratories of Toronto, Cornell, Chicago and Johns Hopkins Universities. Dr. Ralph E. Sheldon, associate in anatomy in the University of Chicago, has been appointed assistant professor of anatomy. He will have charge of histology, embryology and neurology. Dr. F. F. Gundrum, formerly house officer of the Johns Hopkins Hospital, has been made an assistant in anatomy.

